MAINTENANCE PERFORMANCE IN THE SOUTH AFRICAN INDUSTRY

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ABSTRACT

This paper presents the results of a survey conducted on the performance of local maintenance practices. The client base of a leading asset management consultancy was used as the basis for the survey. The sample included a diversity of enterprises across the local industry. Maintenance-related data for 2004 was statistically analyzed; it is presented here in three categories relating to maintenance performance: planning and resource usage, maintenance tactics and time distribution, and performance monitoring and reporting. The aim of the results is to serve as performance benchmarks for the local industry, which will aid in setting targets and identifying initiatives for improvement.

OPSOMMING

Die resultate word getoon van ‘n opname wat gedoen is oor die prestasie van plaaslike instandhoudingspraktyke. Die kliëntebasis van ‘n toonaangewende raadgewende batebestuurfirma is gebruik as basis vir die opname. Die steekproef sluit ‘n verskeidenheid van ondernemings, verteenwoordigend van die plaaslike industrie, in. Instandhoudingsdata vir 2004 is statisties geanaliseer en word aangebied in drie kategorieë met betrekking tot instandhoudingsprestasie: beplanning en gebruik van hulpbronne, instandhoudingstaktiek en tydsverdeling, en prestasiemonitering en rapportering. Die doelwit is om ‘n verwysingspunt vir die plaaslike industrie te stel, vanwaar teikens bepaal en verbeteringsinisiatiewe geïdentifiseer kan word.

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1. INTRODUCTION

Maintenance plays a fundamental role in manufacturing practice, and is influenced by a variety of factors such as workforce skills and commitment, the effectiveness of business processes, and the utilization of technology. Although ample material is published on a diversity of maintenance issues, information relating to local maintenance performance and how it compares with international standards is limited.

This paper presents the results of a survey conducted on maintenance performance in the South African manufacturing industry. The objectives of the study were to determine the current state of maintenance performance, and to derive a list of performance metrics that can be used as benchmarks for self-assessment and comparison against published standards.

In the first part of the paper, we describe the survey, the sample classification, and the descriptive statistics used for presenting the metrics. This is followed by the results and interpretation of the metrics, and remarks on accuracy. Finally, some conclusions are drawn.

2. LITERATURE

The process of measuring and managing performance in modern business is a topical subject, and new developments in the field are continually researched. Maintenance plays an important role in supporting business processes and strategies (e.g. lean manufacturing, just-in-time), and therefore contributes to the overall performance of the business (Woodhouse [1]). The purpose of performance measurement is to provide a basis for improvement. Without measurement there is no certainty that improvement has actually been achieved. Even if there is a perception that things are better, the question to ask is: "Better than what?" (Wilson [2]).

Mitchell [3] defines the process of measuring "best practice" performance and comparing results to corporate (or maintenance) performance as *benchmarking*. Benchmarking can be used to answer the above question. By comparing maintenance metrics against other comparable metrics of leading organizations, information that will help to identify the strengths and weaknesses of existing performance can be obtained (Anderson and Petersen, cited by Yam *et al*. [4]). However, it is difficult to find comparative information that truly represents the population of which a company is part (Jooste [5]). Although benchmarks for world-class performers are available, they are limited, and in some cases (e.g. Campbell [6]) the origin is unknown or based on case studies with specific outcomes (e.g. Chin *et al*. [7]). Basing performance targets on these benchmarks may cause the targets to be over- or under-estimated, resulting in ineffective performance management and ambiguous improvement plans.

3. RESEARCH METHODOLOGY

3.1 The survey

The survey was conducted on the client base of a leading South African asset management consultancy [8], and was based in the consultancy's outsourced maintenance management division, *BURO*. The *BURO* operates by hosting a client's computerized maintenance management system (CMMS) and managing the system for the client. This include an up-to-date asset register, complete preventive maintenance plan, the scheduling and recording of maintenance activities, analysis of maintenance information, and recommendation of improvement initiatives. Although it could be argued that companies making use of a service such as the *BURO* would probably be classified as small- and medium-enterprises (SME), this is not necessarily the case. The sample population covers a wide range of enterprises of different sizes that do not all fit the characteristics of SMEs as outlined by some authors (e.g. Hudson *et al*. [9]).

The survey is based on monthly data collected from the CMMS databases during 2004, and covers asset management key performance areas, such as:

- Planning and resource usage
- Maintenance tactics & time distribution
- Performance monitoring & reporting

3.2 The sample

The sample of client databases was selected on two criteria:

- Uninterrupted service and data recording for the 12-month study period between 1 January 2004 and 31 December 2004.
- Implementation of the CMMS maintenance systems and procedures more than six months prior to the study period – in other words, prior to July 2003.

Based on the criteria, 42 of 110 client databases qualified for inclusion in the sample, or 38.2% of the sample population. This is not out of line with other surveys in manufacturing practice, which have shown response rates around 18% in cases where questionnaires were used (Sohal *et al.* [10]).

The sample has four categories. Figure 1 shows the regional distribution of the sample. The two main regions, hosting 78.5% of the sample databases, are the Western Cape (operating from Cape Town) and Gauteng (operating from Johannesburg). The rest are hosted in Kwa-Zulu/Natal and the Eastern Cape, operating from Durban and Port Elizabeth respectively.

Figure 2 shows the sample distribution classified by industry sector. This classification is based on the International Standard Industrial Classification of all economic activities (ISIC, [11]). The main sectors – 62% of the sample – are the manufacturing of food products and beverages; quarrying of stone, sand and clay; the manufacturing of motor vehicles, trailers and semi-trailers; and the manufacturing of rubber and plastic products. Other manufacturing industries include chemicals and chemical products, paper and paper products, wood and products of wood and cork, textiles, architectural, engineering and other technical activities, and non-metallic mineral products.

Figure 3 shows that more than three-quarters (78.6%) of the sample have an average maintenance workforce of between one and ten artisans. Another 14.3% have an average of eleven to fifteen artisans, while the remaining 7.2% have an average of more than fifteen artisans in their workforce.

As illustrated in Figure 4, two-thirds of the sample process an average of zero to 500 maintenance job cards per month. A further 28.5% process 501 to 1,000 job cards per month, while a further 4.8% process more than 1,000 job cards per month.

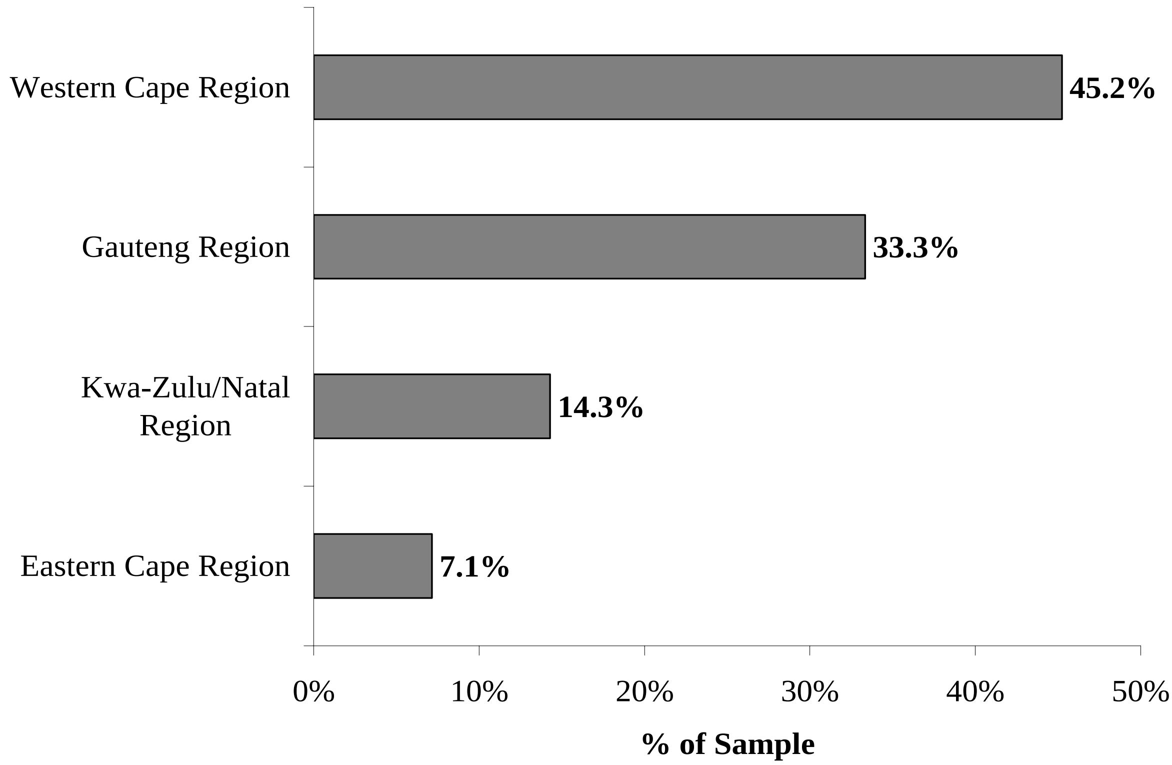


Figure 1: Sample Classification by Region

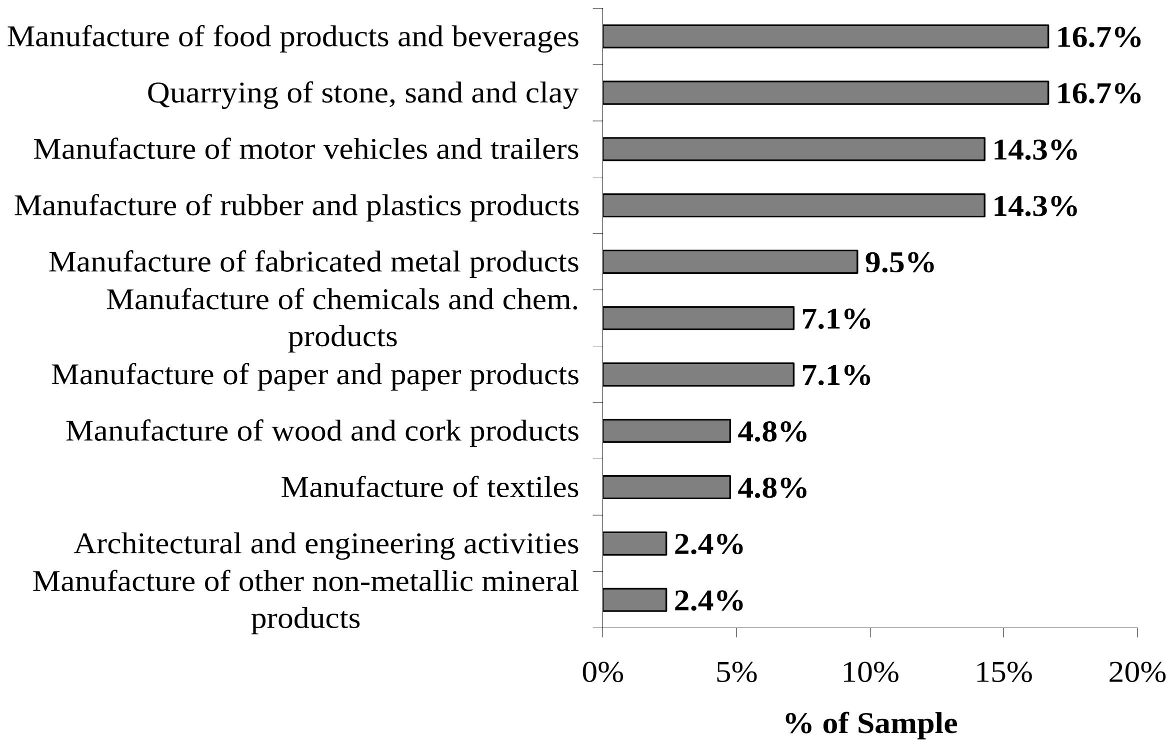


Figure 2: Sample Classification by Industry Sector

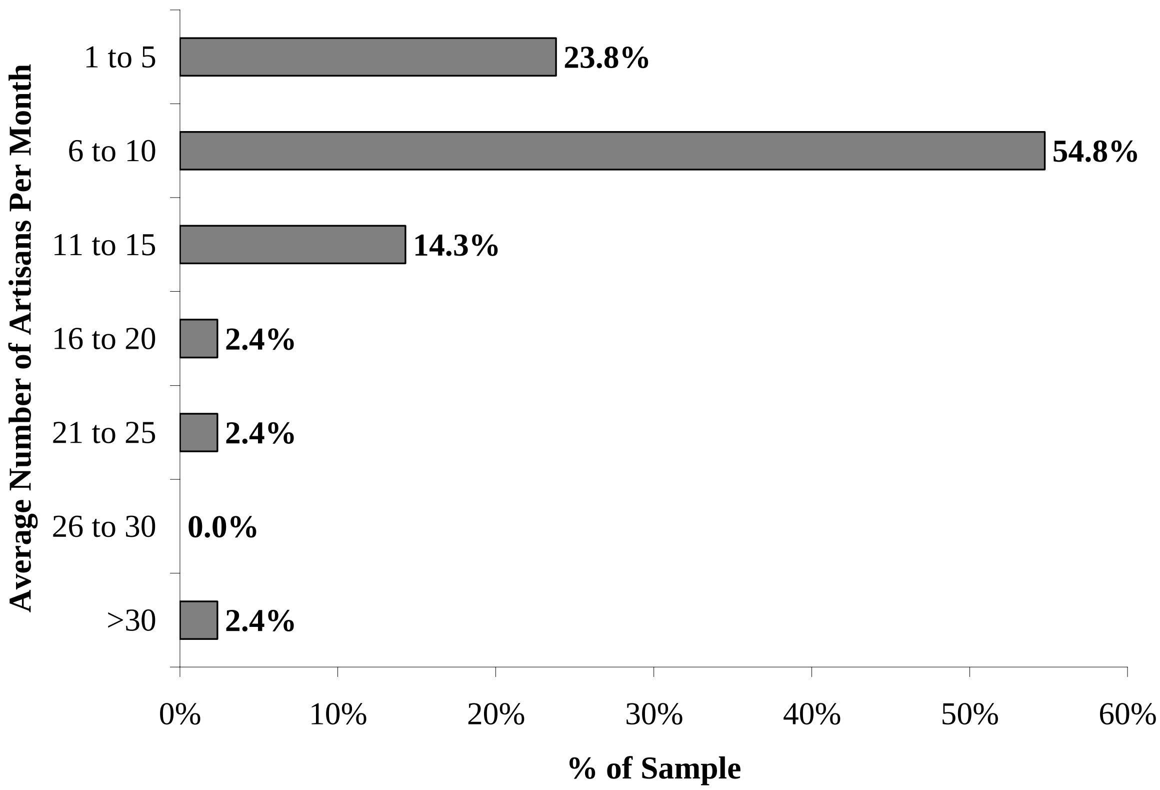


Figure 3: Sample Classification by Average Number of Artisans

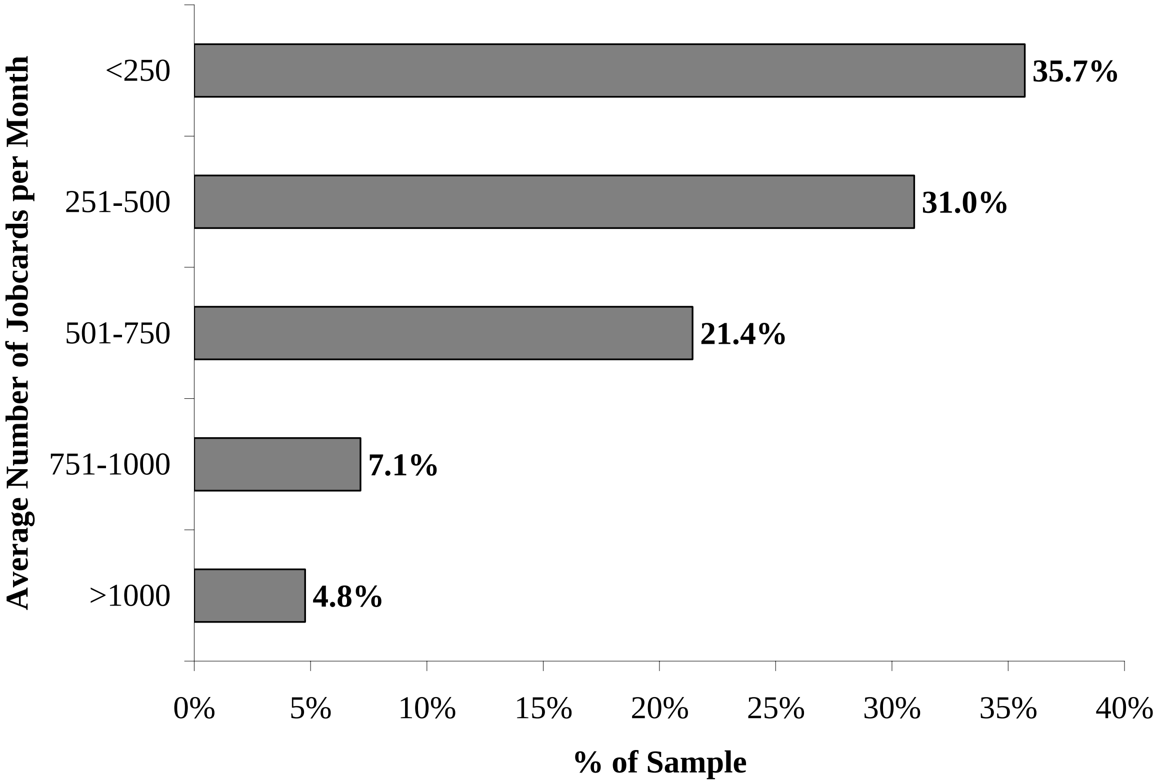


Figure 4: Sample Classification by Average Number of Job Cards per Month

3.3 Descriptive statistics

The data collected during the survey was taken to be distribution-free, and order statistics were used for calculation purposes. No potential outliers were removed to ensure that results were representative of the sample.

The results presented are described through descriptive statistical indicators as calculated by Keller and Warrack [12]. These include measures of location (mean, median), variability (standard deviation, coefficient of variation, minimum, maximum), shape (kurtosis – measure of peakedness, skewness – measure of symmetry) and of relative standing (percentiles and quartiles).

The percentiles and quartiles are useful, as they give detailed information on the distribution of statistics. In Tables I to III the 5th-, 25th- (lower quartile), 50th- (median), 75th- (upper quartile), and 95th-percentiles are listed. The 25th-, 50th- and 75th-percentiles separate the data into four equal parts: 25% of values calculated are smaller than the 25th-percentile, 25% exceed the 75th-percentile, while 25% lie between each of the 25th-, 75th-, and 50th-percentiles. Similarly, 5% of the values are smaller than the 5th-percentile and 5% exceed the 95th-percentile (Devore & Farnum [13]).

4. RESULTS AND INTERPRETATION

The presented metrics are not intended to be a comprehensive list: various other metrics are available for measuring maintenance performance (e.g. listings by Mitchell [3] and Campbell [6]). The metrics presented in this paper are chosen on available data with consistent definitions and calculations throughout the sample population. The metrics are presented in three categories: (i) planning and resource usage, (ii) maintenance tactics and time distribution, and (iii) performance monitoring and reporting.

4.1 Planning and resource usage

In Table 1 the results for the maintenance planning and resource usage category are presented. The metrics are schedule attainment, overtime percentage, job duration, hours per artisan per month, and jobs per artisan per month.

Statistical Indicator	Schedule Attainment	Overtime Percentage	Job Duration [h:mm]	Hours per Artisan	Jobs per Artisan
Mean	78.7%	5.9%	2:30	121	62
Standard Deviation	16.7%	6.4%	1:36	34	38
Coefficient of Variation	21.2%	108.5%	64.0%	28.1%	61.3%
Kurtosis	3.1	3.8	6.3	-0.3	11.0
Skewness	-1.6	1.7	1.9	0.2	2.5
Minimum	19.3%	0.0%	0:00	7	12
5th Percentile	44.4%	0.0%	0:46	71	20
Lower Quartile	74.1%	0.8%	1:27	96	38
50th Percentile/Median	81.3%	4.2%	2:11	117	52
Upper Quartile	90.3%	8.5%	3:06	148	77
95th Percentile	98.4%	19.6%	5:33	178	123
Maximum	99.6%	41.0%	13:08	219	319

Table 1: Descriptive Statistics for Planning & Resource Usage Metrics

Schedule attainment (also known as “schedule compliance” according to Campbell [6], and “planned completion rate” according to Mitchell [3]) is the percentage of scheduled tasks actually completed within a specified time from schedule. For this survey scheduled tasks are defined as predefined and planned maintenance activities that are scheduled and generated through the CMMS. The *time from schedule*-period is equal to 30 days. An average of 78.7% of scheduled tasks (CMMS generated tasks) is completed within 30 days of the scheduled date. Based on the upper and lower quartiles, it follows that three-quarters of the sample – about three-quarters of industry – achieve more than 74.1%, while a quarter of industry is achieving 90.3% and higher. Compared with the Phillips and Lammer’s benchmark of 70% for a four week period (cited by Mitchell [3]), at least three-quarters of industry meets this standard. Using Campbell’s [6] higher benchmark of 92%, the survey shows that less than a quarter of industry meets this target.

Overtime percentage is the maintenance overtime percentage of total time spent on maintenance activities. Overtime includes week-, weekend- and public holiday overtime, while total time equals normal- plus all overtime. Based on maintenance activity durations, an average of 5.9% of maintenance is being done during overtime. It follows from the lower and upper quartiles that the lower quarter of industry does less than 0.8%, and the upper quarter between 8.5% and 41% of maintenance activities during overtime.

Job duration is the total number of man-hours (normal- and overtime hours) required to complete a maintenance job, irrespective of the type of maintenance work. The duration of an average maintenance job is 2 hours 30 minutes. From the upper and lower quartiles it follows that the upper 25% of maintenance jobs exceed 3 hours 06 minutes in duration, while the lower 25% of maintenance tasks are completed in less than 1 hour 27 minutes.

Hours per artisan are the total number of hours an artisan records per month on maintenance job cards. On average an artisan records 121 hours of maintenance activities. Depending on the number of hours in a work week, 121 hours represent 76% utilization in the case of a 160-hour work week, and 67% utilization for a 180-hour work week. Based on the quartiles, the lower quarter of artisans record less than 96 hours per month, while the upper quarter of artisans record more than 148 hours per month.

Jobs per artisan are the total number of jobs that an artisan works on per month. On average, 62 jobs are completed by an artisan, while the lower quarter of artisans works on less than 38 jobs per month and the upper quarter on more than 77 jobs per month.

4.2 Maintenance tactics and time distribution

In Table 2 the results for the maintenance tactics and time distribution category are presented. Since different size companies with different resource- and capacity levels are compared, metrics presented on maintenance types are given in percentages – the number of maintenance man-hours per maintenance type per month, calculated as a percentage of total maintenance man-hours for the same month.

The following definitions were used for the different types of maintenance:

- *Preventive maintenance* consists of time-based tests, inspections, services and/or replacements conducted on regular calendar and/or operating time intervals, in order to avoid failures based on anticipated lifetime (Mitchell [3]).
- *Condition monitoring*[1] (also known as condition based maintenance or predictive maintenance) consists of condition-based operating- and condition measurements and non-invasive tests, for identifying anomalies in advance, in order to avoid failures (Mitchell [3]).
- *Safety maintenance* consists of preventive- and condition-monitoring maintenance as well as unplanned maintenance activities required by safety regulations.

[1] Due to recording variations, preventive- and condition-based maintenance activities were grouped together.

Statistical Indicator	Preventive- & Condition-based Maintenance	Safety Maintenance	Projects & Modifications	Breakdown (Emergency Reactive) Maintenance[2]	Reactive (Non-Emergency) Maintenance	General Maintenance	Change Overs & Settings
Mean	24.1%	3.1%	7.5%	18.0%	29.7%	12.9%	4.6%
Standard Deviation	21.0%	4.6%	9.9%	16.2%	20.8%	13.5%	6.6%
Coefficient of Variation	87.1%	148.3%	132%	90%	70.0%	104.7%	143.5%
Kurtosis	2.7	6.6	3.0	0.9	-0.1	2.3	2.6
Skewness	1.6	2.4	1.9	1.2	0.7	1.5	1.8
Minimum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5th Percentile	0.4%	0.0%	0.0%	0.8%	0.9%	0.0%	0.0%
Lower Quartile	10.3%	0.1%	0.8%	5.8%	13.2%	2.0%	0.0%
50th Percentile/Median	18.4%	1.1%	3.6%	12.3%	26.3%	9.2%	1.6%
Upper Quartile	32.6%	4.2%	9.6%	27.3%	43.2%	19.8%	5.6%
95th Percentile	72.6%	12.6%	31.4%	52.9%	68.8%	45.2%	19.8%
Maximum	100.0%	26.9%	46.2%	73.6%	88.7%	73.8%	31.0%

Table 2: Descriptive Statistics for Maintenance Tactics & Time Distribution

- *Projects and modifications* (also known as pro-active maintenance) consists of non-repetitive activities applied to equipment or the plant prior to or during operation to prevent problems, gain improved reliability, minimize failures, or improve capacity (Mitchell [3]).
- *Reactive maintenance* consists of corrective actions taken on failure or obvious threat of failure (Mitchell [3]). For this survey, reactive maintenance was subdivided into *breakdown (emergency, reactive)* maintenance, consisting of corrective actions taken on failure, and *reactive (non-emergency)* maintenance, consisting of corrective actions taken on obvious, unanticipated threat of failure.
- *General maintenance* consists of non-production related maintenance activities, which include housekeeping, cleaning, and general building and yard maintenance tasks for which the maintenance department is responsible.
- *Change overs and settings* consists of tasks relating to the change over of machines for manufacture of a different type and/or size of product, as well as the pre-production set-up of the machines by maintenance personnel.

On average industry spends 24.1% of total maintenance hours per month on preventive- and condition-based maintenance. From the lower quartile and 95th-percentile, it follows that a quarter of industry spends less than 10.3% on preventive-

[2] Similar to Breakdown Rate presented in section 4.3, Table 3.

and condition-based maintenance, while 5% of industry spends more than 72.6% of its time on these maintenance tactics. A further average of 3.1% of maintenance time is spent on activities relating to safety regulations, with the lower quarter of industry spending less than 0.1%, and the upper quarter more than 4.2% of their time on safety maintenance. On average industry spent 7.5% of maintenance time per month on projects and modifications. Based on the upper and lower quartiles, the lower quarter of industry spends less than 0.8%, while the upper quarter spends more than 9.6% of its time on projects and modifications. All of the above maintenance types can be classified as *planned* maintenance (Yam *et al.* [4]), with a combined average of 34.1% of total maintenance time.

On average 18% of maintenance time is taken up by breakdown (emergency, reactive) maintenance (refer to section 4.3). An average of 29.7% of maintenance time goes into corrective actions taken on anticipated machine failures or reactive (non-emergency) maintenance. The lower quarter of industry achieves less than 13.2% on reactive maintenance, but on the other hand the upper quarter of industry spends more than 43.2% of its time on reactive (non-emergency) maintenance. General (or non-production related) maintenance takes up an average of 12.9% of maintenance time, while a quarter of industry spends more than 19.8% of its time on this type of maintenance work. The above types can be classified as *unplanned* maintenance, with a combined average of 58.5%.

4.3 Performance monitoring and reporting

The results for the performance monitoring and reporting category are presented in Table 3. The metrics are breakdown rate, breakdown count, mean time to repair, root cause percentage, and downtime.

Statistical Indicator	**Breakdown Percentage**	**Breakdown Count**	**Mean Time To Repair [h:mm]**	**Root Cause Percentage**	**Downtime**
Mean	18.0%	97	2:21	28.5 %	288
Standard Deviation	16.2%	143	1:36	36.8%	840
Coefficient of Variation	90.0%	147.4%	68.1%	129.1%	291.7%
Kurtosis	0.9	10.9	21.8	-1.0	23.0
Skewness	1.2	3.1	3.5	0.8	4.7
Minimum	0.0%	1	0:16	0 %	0
5^{th} Percentile	0.8%	4	0:42	0 %	2
Lower Quartile	5.8%	17	1:19	0 %	13
50^{th} Percentile/Median	12.3%	47	2:09	0 %	48
Upper Quartile	27.3%	110	2:50	62.5%	169
95^{th} Percentile	52.9%	429	4:36	96.3%	1804
Maximum	73.6%	907	16:00	100.0%	6214

Table 3: Descriptive Statistics for Performance Monitoring & Reporting Metrics

Breakdown (emergency reactive) maintenance, as in Table 2 column 4, is by definition the same as *breakdown percentage*, which is the percentage of total maintenance man-hours spent on breakdown (emergency, reactive) maintenance. On average 18% of maintenance activities are spent on breakdown maintenance. From the lower quartile it follows that the lower quarter of industry spends less than 5.8% of its time on breakdown maintenance; but also based on the 95th-percentile, 5% of industry spends more than 52.9% of its time on breakdown maintenance. It follows that a quarter of local industry is on par with benchmarks for breakdown percentage, according to Bahrami (cited by Mitchell [3]) (~2 %) and Yam *et al.* [4] (~7%).

Breakdown count is the number of failure occurrences per month. The difference between the mean (which is sensitive to outliers) and the median (which is insensitive to outliers) is 50 failures. It can therefore be deduced that a number of industries have very high breakdown counts that bias the mean. This is seen from the 95th-percentile (429) and the maximum (907). The median will therefore be a more suitable measure of location. From the lower- and upper quartiles it follows that the lower quarter of industry achieves breakdown counts of 17 and fewer per month, while the upper quarter of industry tallies 110 and more breakdown counts per month.

Mean time to repair is a measure of maintainability (Campbell [6]), indicating the mean time (in man-hours) to repair after a failure has occurred. On average it takes industry 2 hours 21 minutes to repair a failed piece of equipment. Based on the 5th-, 25th- and 95th-percentiles, the lower 5% of industry repairs failures in less than 42 minutes; the lower 25% takes less than 1 hour 19 minutes, while the upper 5% of industry takes longer than 4 hours 36 minutes to repair a failure.

Root cause percentage is defined as the number of failure occurrences, formally analyzed and documented up to root cause level, as a percentage of total failure occurrences. An average of 28.5% of failed machines are analyzed to find the root cause of the failure. The median is equal to zero, indicating that there are a number of industries recording very high root cause percentages, biasing the mean. It follows that 50% of industry does not analyze to root cause level. The upper quarter of industry, however, analyses more than 62.5% of their failures to find the root causes, while 5% of industry analyses between 96.3% and 100% of their failures to root cause level.

Downtime is defined as the period of time during which a machine is not in a condition to perform its intended function (Campbell [6]). It is different from breakdown (emergency, reactive) maintenance, since it only represents the duration of lost production, whereas breakdown (emergency, reactive) maintenance represents the total man-hours spent on corrective actions on failed equipment. Downtime is recorded from a maintenance perspective (on maintenance job cards) and therefore deviations from production performance may be expected in cases where parallel measurements are recorded. Large deviations can be seen for the downtime information in Table 3. The data from the survey indicates an average of 288 hours of downtime per month, a standard deviation of 840 hours and a maximum of 6,214 hours per month! These statistics appear suspicious, but can be explained when compared to the median, upper quartile, and 95th percentile. The average and standard deviation are sensitive to outliers, while the median, quartiles, and percentiles are not. Based on the variation between the ranges of the indicators of relative standing – 13 hours (first quarter), 35 hours (second quarter), 121 hours (third quarter), 6,045 hours (fourth quarter) and 4,410 hours (upper 5%) – it can be concluded that outliers are indeed responsible for the distorted effect on the average. The lower quartile (13 hours/month), median (48 hours/month) and upper quartile (169 hours/month) are therefore suggested as estimates for benchmarking under-, average-, and top downtime performance.

Metric Description		5th Percentile Lower Limit	Accuracy (95% Conf)	5th Percentile	95th Percentile	Accuracy (95% Conf)	95th Percentile Upper Limit
Planning, Scheduling & Utilization	Schedule Attainment	19.8%	24.6%	44.4%	98.4%	1.1%	99.5%
	Overtime Percentage	0.0%	0.0%	0.0%	19.6%	2.4%	22.0%
	Job Duration	00:40	00:06	00:46	05:33	00:09	05:42
	Hours per Artisan	70	1	71	178	4	182
	Jobs per Artisan	18	2	20	123	6	129
Maintenance Tactics	Preventive- & Condition-based Maintenance	0.1%	0.3%	0.4%	72.6%	6.2%	78.8%
	Safety Maintenance	0.0%	0.0%	0.0%	12.6%	1.4%	14.0%
	Projects & Modifications	0.0%	0.0%	0.0%	31.4%	2.3%	33.7%
	Breakdown (Reactive, emergency)	0.4%	0.4%	0.8%	52.9%	3.5%	56.4%
	Reactive (Non-emergency)	0.2%	0.7%	0.9%	68.8%	5.1%	73.9%
	General Maintenance	0.0%	0.0%	0.0%	45.2%	3.3%	48.5%
Performance Measurement	Breakdown Percentage	0.4%	0.4%	0.8%	52.9%	3.5%	56.4%
	Breakdown Count	3	1	4	429	44	473
	Mean Time To Repair	00:34	00:07	00:42	04:36	00:39	05:15
	Root Cause Percentage	0.0%	0.0%	0.0%	96.3%	1.6%	97.9%
	Downtime	1	1	2	1804	785	2589

Table 4: Accuracy Limits and Intervals for the 5th- and 95th-percentiles

4.4 Accuracies

The accuracy on the 5th-, 50th-, and 95th-percentiles and the lower (25th-percentile) and upper (75th-percentile) quartiles are calculated. Kendall and Stuart's [14] approach was followed for the calculation of the accuracies. The advantage of this approach is that it is based on order statistics, and is thus distribution-free and insensitive to outliers. For the 5th- and 95th-percentiles, as well as the lower and upper quartiles, one-sided 95% confidence intervals were calculated, with two-sided confidence intervals for the 50th-percentile (median). Accuracies for the 5th-, 25th-

(lower quartile), 75th- (upper quartile) and 95th-percentiles can be interpreted as follows: it is 95% certain that the 5th- and 25th-percentiles of the population will be greater than the lower confidence limit, while it is 95% certain that the 75th- and 95th-percentiles will be less than the upper confidence limit. For the 50th-percentile it is 95% certain that it will fall between its lower and upper confidence limits. The accuracies for the 5th- and 95th-percentiles are shown in Table 4, for the lower quartile and upper quartile in Table 5, and for the 50th-percentile/median in Table 6. Reasons for poor accuracies are the relatively small sample size and variations in maintenance procedures and data recording at the sample companies. There is also proof of extreme recordings (outliers) affecting the 5th- and 95th-percentiles, as can be seen by the accuracies of the schedule attainment 5th-percentile and downtime 95th-percentile, which are 24.6% and 785 hours respectively.

Metric Description		Lower Quartile Lower Limit	Accuracy (95% Conf)	Lower Quartile	Upper Quartile	Accuracy (95% Conf)	Upper Quartile Upper Limit
Planning, Scheduling & Utilization	Schedule Attainment	68.7%	5.4%	74.1%	90.3%	3.2%	93.5%
	Overtime Percentage	0.5%	0.3%	0.8%	8.5%	0.7%	9.2%
	Job Duration	01:23	00:04	01:27	03:06	00:10	03:16
	Hours per Artisan	93	3	96	148	3	151
	Jobs per Artisan	37	1	38	77	2	79
Maintenance Tactics	Preventive- & Condition-based Maintenance	9.8%	0.5%	10.3%	32.6%	1.8%	34.4%
	Safety Maintenance	0.1%	0.0%	0.1%	4.2%	0.6%	4.8%
	Projects & Modifications	0.6%	0.2%	0.8%	9.6%	1.0%	10.6%
	Breakdown (Reactive, emergency)	5.2%	0.6%	5.8%	27.3%	1.4%	28.7%
	Reactive (Non-emergency)	12.5%	0.7%	13.2%	43.2%	1.7%	44.9%
	General Maintenance	1.5%	0.5%	2.0%	19.8%	1.4%	21.2%
	Change Overs & Settings	0.0%	0.0%	0.0%	5.6%	1.5%	7.1%
Performance Measurement	Breakdown Percentage	5.2%	0.6%	5.8%	27.3%	1.4%	28.7%
	Breakdown Count	16	1	17	110	14	124
	Mean Time To Repair	01:15	00:04	01:19	02:50	00:10	03:00
	Root Cause Percentage	0.0%	0.0%	0.0%	62.5%	8.9%	71.4%
	Downtime	11	2	13	169	17	186

Table 5: Accuracy Limits and Intervals for the lower- and upper quartiles

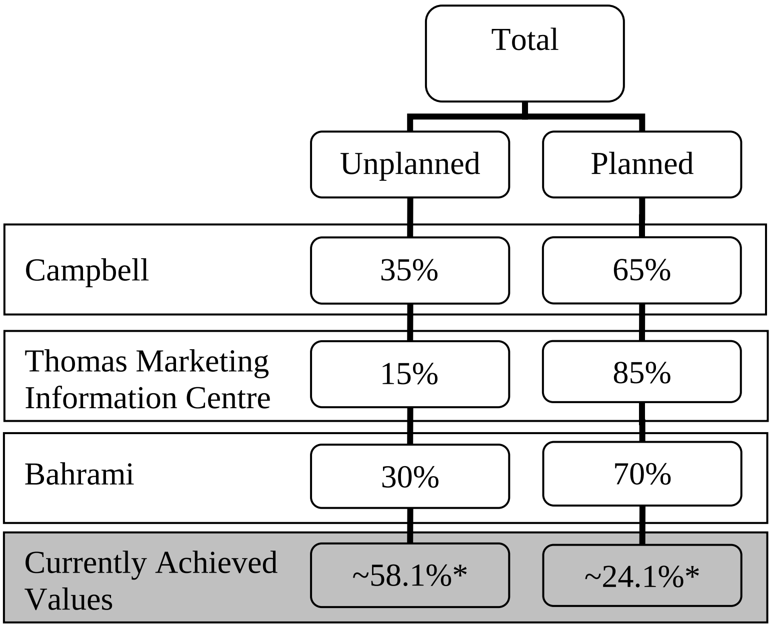
Metric Description		50th Percentile/ Median	50th Percentile Lower Limit	Accuracy (90% Conf)	50th Percentile Upper Limit
Planning, Scheduling & Utilization	Schedule Attainment	81.3%	76.7%	9.8%	86.5%
	Overtime Percentage	4.2%	3.6%	1.1%	4.7%
	Job Duration	02:11	02:06	00:12	02:18
	Hours per Artisan	117	115	6	121
	Jobs per Artisan	52	50	5	55
Maintenance Tactics	Preventive- & Condition-based Maintenance	18.4%	17.0%	2.3%	19.3%
	Safety Maintenance	1.1%	0.9%	0.5%	1.4%
	Projects & Modifications	3.6%	2.9%	1.4%	4.3%
	Breakdown (Reactive, emergency)	12.3%	11.1%	2.4%	13.5%
	Reactive (Non-emergency)	26.3%	24.4%	4.5%	28.9%
	General Maintenance	9.2%	7.8%	2.3%	10.1%
	Change Overs & Settings	1.6%	1.2%	0.9%	2.1%
Performance Measurement	Breakdown Percentage	12.3%	11.1%	2.4%	13.5%
	Breakdown Count	47	38	16	54
	Mean Time To Repair	02:09	02:01	00:12	02:13
	Root Cause Percentage	0.0%	0.0%	2.2%	2.2%
	Downtime	48	37	23	60

Table 6: Accuracy Limits and Intervals for the 50th-percentile/median

5. CONCLUSIONS

Although the sample was not random, and was based on the premises of a single asset management service provider, the figures probably differ only marginally from those of the full population of maintenance departments in the sectors listed in this paper.

In comparison with published benchmarks of recent years, local maintenance departments are falling short with regard to preferred maintenance tactics. Campbell [6] suggests a 35:65 ratio for unplanned to planned maintenance, while the Thomas Marketing Information Centre (cited by Mitchell [3]) and Bahrami (cited by Mitchell [3]) suggest ratios of 15:85 and 30:70 respectively (Figure 5). The averages of 24.1% and 58.1% on planned and unplanned maintenance respectively (as shown in section 4.2) currently achieved by local industry are way off in comparison with the above standards, showing that South African enterprises are still spending most of their time on reactive maintenance.



***Based on average**

Figure 5: Comparison between published benchmarks and currently achieved values

Under-performance in analysis of the root causes of breakdown contributes to the negative planned to unplanned maintenance ratio highlighted above. Based on the *Root Cause Percentage* (refer to Table 3), 50% of industry does not analyse breakdown occurrences to root cause level, illustrating industry's tendency towards reactive maintenance.

This suggests that the local maintenance workforce is efficient but not effective. On average, artisans are utilized between 62% and 70% per month (Figure 6), based on the average 121 hours worked per month and a 40- to 45-hour work week (as outlined by the Basic Conditions of Employment Act [15]). Artisan utilization is therefore in line with the 65% standard suggested by some industry experts [8]. Based on the average percentage of unplanned maintenance (58.1%) and the relatively high artisan utilization (62-70%), it follows that the local maintenance workforce is efficient, but not effective – that is, they are performing the wrong maintenance activities well.

The results shown for schedule attainment in Table 1 are positive. An average of 78.7% of scheduled maintenance is completed within four weeks from the intended date, while a quarter (upper quartile) of industry is achieving more than 90.3%. Since schedule attainment is a measure of work planning and control performance, we conclude that companies making use of a formal maintenance management system – as in the case of the sample – will achieve levels of performance conforming to current published standards (refer to section 4.1).

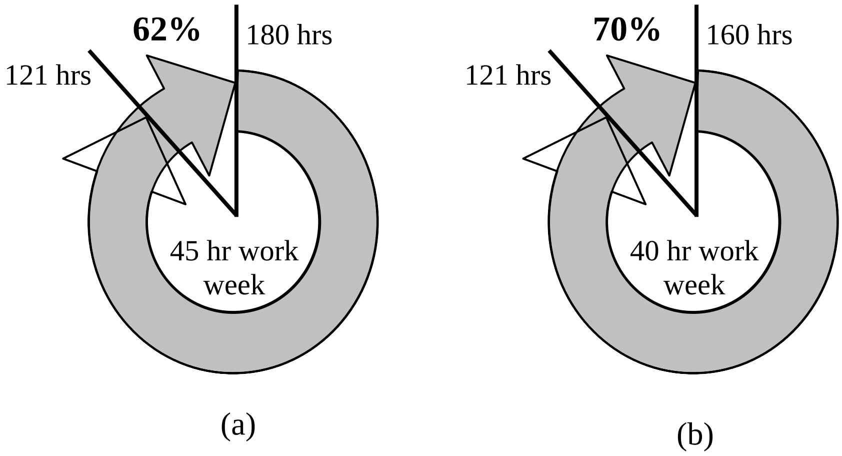


Figure 6: Labour utilization for (a) 45-hour and (b) 40-hour work week

Based on the downtime results in section 4.3, it is clear that this important measure of lost production time is not satisfactorily recorded. Although the intention of this study was not to investigate recording practices, probable reasons for the poor recording of downtime could be: confusing or unclear definitions of breakdown man-hours (breakdown job duration) and of downtime hours (lost production duration); ineffective procedures; or parallel/independent performance measurement systems run by both the production and engineering departments.

Maintenance managers should find the indicators presented in this paper useful for benchmarking their maintenance department's performance against others in the local industry. The percentiles can be used to determine a maintenance department's position relative to the industry standard, allowing for targets to be set to drive improvement initiatives.

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