# Improving Productivity Through Tool Tracking

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Abstract

A tool management system should be able to keep a record of the locations of all tools at all time. Such a system requires continual, accurate and consistent entry of tool data and this is only possible in highly ordered environments. In less ordered environment, it is difficult to maintain such rigorous data entry and data will eventually becomes degraded and obsolete. Here we describe a tool tracking system suitable for less ordered conditions which are representative of the majority of real shopfloors. Such a system is capable of monitoring tool movement, and able to update its records of tool data while tools are in use. A simulation experiment is run to relate the effect of the system on productivity.

**Keywords:** tool management, tool tracking

## 1 Introduction

Tool management has been defined as a strategy that aims at resolving problem related to various tool activities including acquisition, storage, database development, selection and allocation, inspection, presetting, delivery, loading, monitoring, replacement planning and inventory control of tools [1].

The objective of tool management may be described as ensuring the five 'rights' [2, 3] – The right tool. At the right place. At the right time. In the right condition. At the right cost.

A tool management system is an organised approach to ensuring that tooling is available for use to achieve the goals of the production plan [4]. It should be able to deliver these five rights. Engler [5] and Jones [6] believe that a good tool management system contributes greatly to increase in productivity and efficiency.

## 2 Problems in Tool Management

The ultimate aim of any tool management system is to eradicate tool unavailability [7]. A tool may be made unavailable due to;

- It is being used on a job.
- Its useful life has ended and it needs to be renewed.
- It is hoarded or lost somewhere on the shopfloor, its location unknown.

The problem of tool unavailability is very real as highlighted by Mason [8];

- 30% - 60% of a shop's tooling inventory is somewhere on the shopfloor.
- 16% of scheduled production cannot be met due to tool unavailability.
- 40% - 80% of a foreman's time is spent looking for, and expediting, materials and tools.
- 20% of the operator's time is spent searching for cutting tools.

In a survey by Perera and Shafaghi [7], companies were asked to rank six well known tooling problems in order of importance within their business unit. The results were as follows;

1. High tool variety
2. Tool unavailability
3. Tool tracking and control
4. High tool inventory
5. Lack of tool services
6. Cost of tooling

Thus one of the functions essential for an effective tool management system is the ability to monitor tool location [8, 9].

Tool movements may occur due to assignment of tools to machines, being shared among machines or replacement when they reached the end of their useful lives. Whatever the reasons, it is important to control and monitor these movements so that tool location may be known and tools may be made available when needed.

## 3 Identification Systems in Tool Management System

Tools may be monitored either manually or through a computerised system. However manual tracking of tools is generally not recommended except for very small shopfloors [8, 9]. The trend now is going from manual to computerised tool management systems.

Mason [8], believes that an effective tool identification system is a preliminary requirement to a tool management system. Being able to uniquely identify tools will ease their control and monitoring. With computerised systems, automatic identification (AutoID) has become the trend.

AutoID systems are systems which automate data entry and/or automatically identify information [10]. This allows data to be managed accurately and tracked in real-time.

The purpose of an AutoID system in tool management is not only to identify tool but also to maintain information such as location, inventory, purchasing data, remaining life, tool offsets, and cutting parameters. In some implementations the AutoID system is limited to only recognising the identity of the tool while the host computer maintains the rest of the tool data [8].

AutoID technologies that are usually used in tool management are barcodes and radio frequency tags. Morris Tooling used barcoded labels to identify the assembled tools when they arrive at the machine [11]. The setting data for this set of tools is then downloaded from the computer into the machine's control. Small [12] described the use of radio frequency tags attached or embedded in tools for tool management systems. Sandvik Coromant [13] a supplier of metalworking products offers a range of electronic tags that can be installed in their tool holders.

Some application use both barcodes and radio frequency tags to keep track of tools [5, 8]. For example, a palletized containers of tools are identified by using barcoded labels and the individual tools are identified using tags and barcodes [14].

Barcodes may facilitate tool control but they are limited to a relatively short read range and they do not work well under harsh environmental conditions. The use of radio frequency tags solves this problem but the tags used are of the passive type. It does not carry its own power source. It will only be energised when it comes within the transmission field of the reader. A passive transponder may have a range of more than a meter but embedded in metal, this range will reduce considerably to just a few centimeters. Thus, to update tool data, an operator has to place the tool near a reader to ensure data is captured. Once a tool is lost or not in the operator's possession, this cannot be done and tool data will degrade.

Such a system will require accurate and consistent entry of data and is suitable for highly automated companies that are capable of exerting complete control of its tools and accessories [3]. In non-fully automated companies strict tool control is difficult to maintain and such a system is not suitable. Tool data will become degraded especially relating to information on tool location because tools are shared among different machines at various time without the knowledge of the tool management system.

In these less ordered conditions, which are representative of the majority of real shopfloors, what is needed is a tracking system which is capable of monitoring tool movement, and is able to update its records of tool locations while the tools are being used. This paper describes a tool tracking system suitable for implementation in this environment. This system is called the active tool tracking system [15]. It is the first active tool tracking system designed for tool management.

## 4 Active Tool Tracking System

The system embedded each tool with a miniature battery-powered transmitter. This transmitter may be radio, infrared, ultrasonic or some combination of these. Each transmitter sends out a short burst of signal periodically. Between these burst of signal are periods of dormancy to minimise power consumption. These burst of signals contains coded information to identify the tool.

Detector stations are placed in strategic locations around the machine shopfloor. These detector stations contain receivers tuned to the same frequency as the tool transmitters. As a tool passes close to a detector station, the signal is detected, decoded and the tool identity passed to a central computer. Tool location is determined by identifying which detector station received the signals.

The power of the transmitters, and the sensitivity of the receivers, is deliberately limited so that ideally, each detector station would exclusively monitor a particular well-defined area such as a room or corridor. Figure 1 shows a simplified diagram of the system. Three tools T1, T2 and T3 and two receivers Rx1 and Rx2 are shown. T1 is within the reception region of Rx1 only, while T3 is within the reception region of Rx2 only. T2 is within the region of reception of both receivers. The interface performs the decoding function to enable tool identification.

However, radio (or other) transmission cannot be exactly bounded and is subject to reflection and attenuation. Thus, a detector may be unable to detect a tool passing nearby or it might detect tools further away. This means that the system is subject to unavoidable random disturbances and cannot operate with 100% precision. The effect of this will be discussed later.

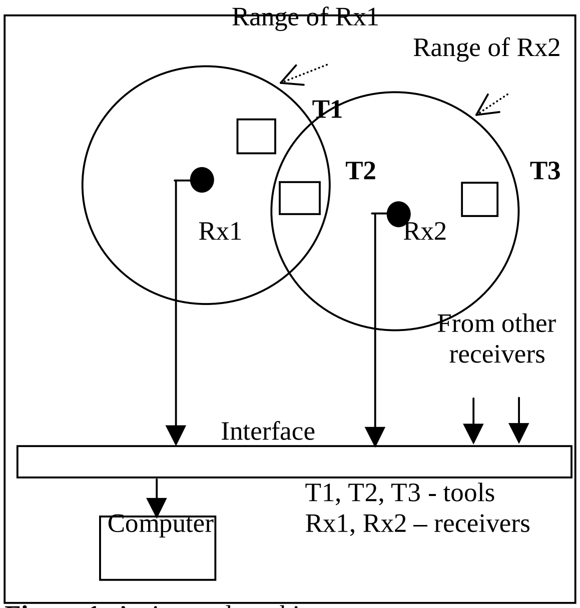

**Figure 1.** Active tool tracking system.

## 5 Feasibility of System

A prototype system was built and experiments were conducted to test its tracking capability. A 418 MHz FM radio transmitter was embedded in a metal container representing a tool body. The coded signals are allowed to escape from the container through a small aperture. A detector station was set up within the laboratory using an FM 418 MHz radio receiver embedded in an earthed metal box. A small aperture in one of the faces of the box allowed the radio waves from the transmitter to reach the receiver antenna.

The range of reception of the transmitted signal were determined by conducting a large number of tests. In these tests, the 'tool' was first removed to a position so distant from the detector that there is no reception. It was then moved in a straight line towards the detector. The point where reception was first achieved is noted. This was repeated holding the 'tool' with the transmission aperture in different fixed orientations.

The results of these tests are shown in Figure 2. It shows that there are 3 regions of reception;

- Region D (Definite detection)

In this region, any signals from a tool transmitter will definitely be detected.

- Region N (definite Not detected)

If the tool is located too far away from the receiver, it is definitely not detected.

- Region M (May be detected)

Between these two regions there is another (region M) in which there is a probability $P_M$ ($0<P_M<1$) that the 'tool' is detected. It is not possible to define $P_M$ as a function of tool/receiver distance since there are too many random fluctuations in sensitivity due, for example, to movements of other bodies in the proximity of the receiver, or to the manner in which the tool is being transported.

The size of these regions depends on certain parameters. These parameters include the transmitter power (including the effect of the transmitter aperture) and the receiver sensitivity (including the effect of the receiver aperture). Thus, the region D (and hence M), can be enlarged by using a more powerful transmitter or a more sensitive receiver. In any particular application these parameters will be choosen to give the degree of location resolution required.

However, the optimal choice is not obvious. This is because if a more powerful transmitter or a more sensitive receiver is used, the D (and M) regions may be too large to accurately locate tools and a tool might be simultaneously detected by several detector stations. If, on the other hand, the D (and M) regions are made too small in order to obtain precise detection, then tools might pass close to detector stations without being detected at all and a large number of detector stations may be needed to avoid this.

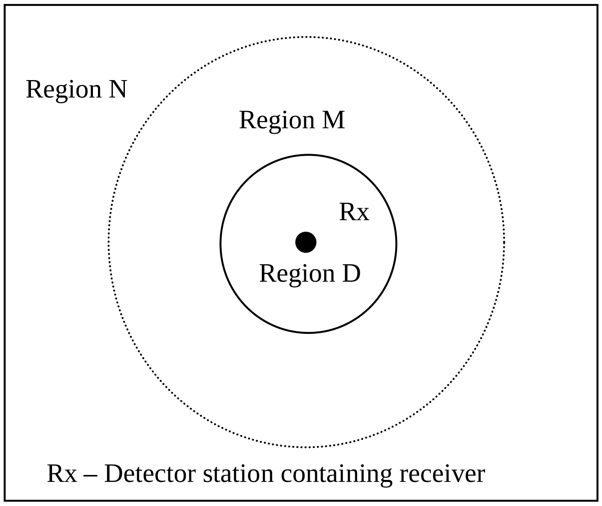


**Figure 2.** Region of detection.

## 6 Location Prediction

The location of tools may be predicted based on which receiver detected a signal. Placing a detector station at each doorway to a room or an area will assist in tracking the movement of tools in or out of this areas.

The flowchart in Figure 3 illustrates the procedure used to predict tool location. Tool tracking system that uses barcodes and passive tags would require data to be updated. Thus a missing tool will remain lost until someone updates it. With this active tool tracking system, a missing tool will be 'found' once it comes within range of a detector station.

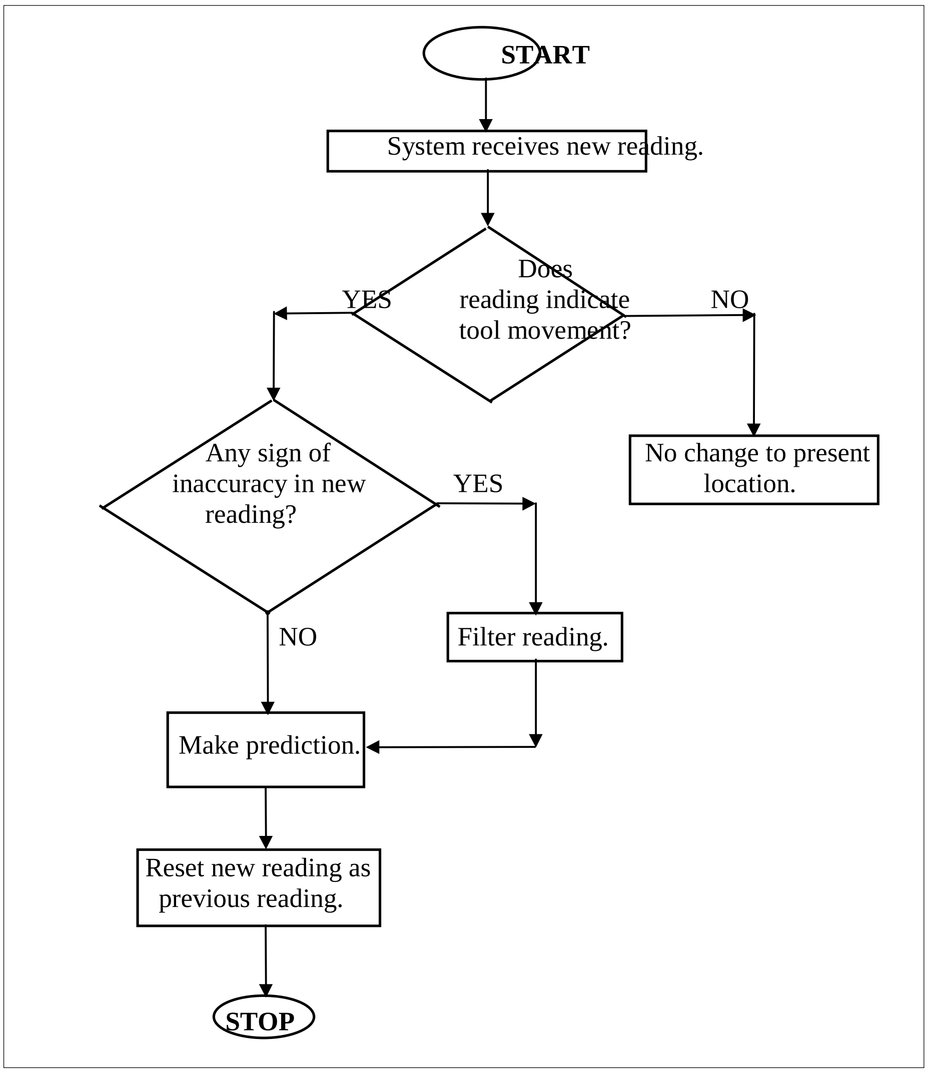


**Figure 3.** The procedure to predict tool location.

## 7 Evaluation of System - Simulation

The system predicts a tool's location by analysing which receiver(s) detected its signal and where its location was previously assumed. However, because the transmission cannot be exactly bounded and the problems of reflection and attenuation, a tool may pass by undetected. Therefore, the system may not operate at 100% effectiveness.

Thus, to assess the effects of the system on productivity, a computer model of a factory shopfloor was set up so that important parameters could be easily varied. The shopfloor model consists of the following elements;

i) Workstation : Three workstations, each capable of processing any job provided the required tools are available. Processing time is fixed at 5 time units. The simulation runs for 4000 time units so that the maximum possible number of completed jobs is 2400.

ii) Tool replacement facility : This is simulated with the task of renewing tool life once it has reached the end of its useful life. A tool is assumed to have reached this after processing a predetermined number of parts. In this model this value is choosen to be 10.

iii) Tool store : A centralised tool store is simulated to store unrequested tools, to send 'dead' tools to the tool replacement facility and to to accept renewed tools from the tool replacement facility.

iv) Tools : Four types of tools are simulated which are equipped with embedded transmitters as described above.

v) Jobs : Jobs are grouped according to the tool type each requires. First In First Out strategy is used at each workstation and a job is dispatched to a workstation when, and only when, it has all of the required tools.

vi) Detector stations : These contain receivers tuned to the frequency of the tool transmitters. A variable detection probability ($P_{det}$) is assigned to each detector station.

vii) Lost tool module : It simulates the loss of tools on the shop floor. A tool is defined as lost when it is diverted from its intended destination. It reflects, for example, the event of a tool being 'pinched' from another workstation or tool replacement facility or the store. Any lost tool will be sent to this module which will then decide at random where it will be diverted. There is uniform likelihood of it being found at any particular point on the shopfloor.

The shopfloor takes advantage of the information on tool location provided by the detector stations to prevent tool hoarding. Whenever the system realises that a workstation has more than one of the same tool type in its location, an action is invoked to get that extra tool back to the tool store so that it can be made available.

These experiments involve two shopfloor models. One model has 100% tool duplication (called Model I) and the other 200% duplication (called Model II). Duplication of 100% means that the number of tool copies for each type of tool is equal to the number of machines or workstations [16].

In this experiment all other values are fixed while $P_{det}$ and the degree of tool loss are varied. Productivity is measured by the total number of jobs completed at the end of each run. Figure 4 shows the results of this experiment for Model I. Figure 5 shows the results for Model II.

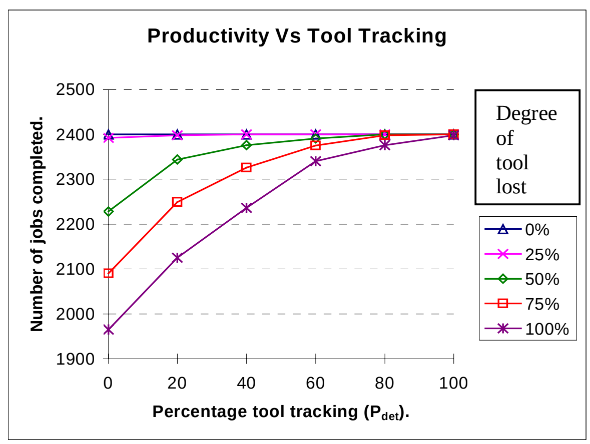


**Figure 4.** Productivity : MODEL I.

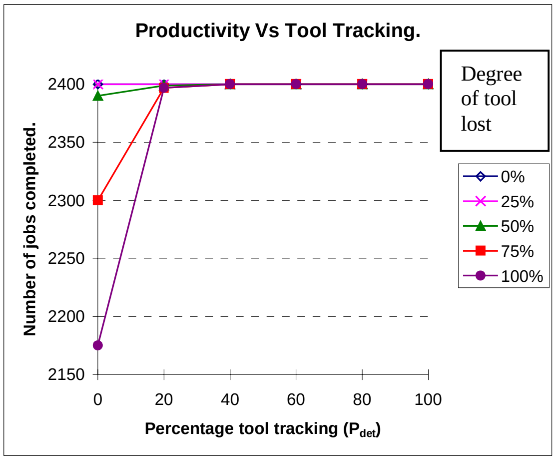


**Figure 5.** Productivity : MODEL II.

The graphs in Figure 4 and Figure 5 show that, at;

- 0% tool loss

This is the case for the ideal shopfloor : tools are never lost or hoarded. Both models shows that in this case, varying the efficiency ($P_{det}$) of the detector stations has no effect on productivity. Obviously tools do not need to be tracked if they do not get lost.

- 25% tool loss

At this level of loss, both models show that 100% productivity is still virtually maintained.

- 50% tool loss

For Model I, if $P_{det}$ = 0 (detector station ineffective) the productivity falls to 93%. However this improves as the detectors' effectiveness is increased until finally productivity is pushed up to 100% when $P_{det}$ = 80%.
Model II shows a slight reduction in productivity at $P_{det}$ = 0% but is quickly raised to almost 100% when $P_{det}$ is just 20%.

- 75% tool loss

Model I shows that without any tool tracking ability, productivity decreases to 87% but it can still be raised back to 100% by implementing a completely effective tracking system.
Model II shows that there is a noticable drop in productivity (95%) without any tool tracking but improves considerably at 20% tracking efficiency.

- 100% tool loss

With this level of total chaos and without any tool tracking ability, productivity for Model I decreases to 87% but with 100% tracking efficiency, productivity is raised to the maximum level.
Model II also shows a marked decrease in productivity (down to 90%) but improves quickly to virtually 100% at just 20% tracking efficiency.

For this simulated shopfloor, the results showed that in an ideal case where strict control of tools is possible and tools are never diverted from their intended destinations, the tracking system will have no effect on productivity. But in cases where tools are subjected to a degree of loss, the tracking system is able to improve productivity quite markedly even if it is not functioning perfectly. This becomes more noticable in the case of Model I where the number of tools is less.

Improvement can be gained by implementing a tool tracking system. This becomes more apparent the greater the degree of tool loss and the lesser the numbers of tools available for sharing among workstations.

## 8 Conclusion

The problems of tracking tools has been highlighted and the inadequecy of the existing computerised tool management system has been discussed. A novel tool tracking system is described which can easily be implemented in a factory. Each tool has embedded within it a transmitter which emits signal containing identifying code. Detector stations consist of receivers tuned to the same frequency as the transmitter are strategically placed around the shopfloor to detect passing tools. By this means a central computer can track each tool and prevent tool loss. Simulation experiments conducted show that the system is effective in increasing productivity particularly in situations where tool loss is high and lesser tools are shared among workstations.

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