

# An Empirical Modelling Approach to Self-Adjusting Environmental Vehicle Reversing Alarms

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## Abstract

The Health and Safety Executive (HSE) estimates that 25% of all work-related road deaths are caused by reversing vehicles (Brake - the Road Safety Charity). This paper uses an Empirical Modelling (EM) approach to analyse techniques by which vehicle reversing alarms can be “smarter”. Beneficiaries of the techniques include the driver, pedestrians and nearby residents. An original EM model is created in order to illustrate how Empirical Modelling is helpful in this context to educate users as to how a “smarter” vehicle reversing alarm works.

## 1 Introduction

The focus of this paper is to study the techniques by which a standard reversing alarm can be improved to attempt to reduce the 25% of all work-related road deaths which are caused by reversing vehicles (Brake - the Road Safety Charity).

The purpose of the EM model produced is twofold. Firstly, it is to investigate the EM approach and the perceived benefits as well as drawbacks as a result of choosing such an EM approach over more conventional approaches. Secondly, it can be used as an educational tool to teach individuals the techniques that a “smart” reversing alarm makes use of, in an experiential way.

## 2 Reversing alarms and EM concepts

Most of us are aware of a simple reversing alarm which beeps to indicate that the vehicle is reversing. There are a number of problems associated with such a simple reversing alarm, and even these simple alarm systems are not deployed on many vehicles. This section describes the techniques by which a reversing alarm can be improved in a number of areas, and discusses the relevance of EM as an approach to model the “smart” reversing alarm.

### 2.1 Functions of a “smart” reversing alarm

Reversing alarms are alarms which sound when a vehicle is reversing. “Smart” reversing alarms do a

bit more to benefit different users and are more environmental.

One such technique is to sense the ambient noise level at specified time intervals and adjust the volume of the alarm accordingly. This ensures firstly that the alarm is always heard, whether the vehicle is in a noisy environment such as a quarry or a quieter environment such as a work yard in a rural location. The alarm will always be adjusted to be 10dB above the sampled ambient noise level in the area. Decibels are a logarithmic scale and an increase of 10dB sounds roughly twice as loud. Secondly, this makes the alarm more “environmental” meaning that there is reduced noise pollution, since the alarm is not at a fixed level which could potentially be much higher than ambient noise levels in the area and therefore more clearly audible at nearby residential properties.

Another technique is to detect whether there is actually an obstructing object behind the vehicle. This means that the alarm only sounds when it is required: again minimising noise pollution. An extension of this technique further is to sound the alarm in three stages. The first warning is a slow bleep, the second is an urgent bleeping and the final stage is a constant tone. The benefit of this technique is increased feedback, both for the driver and for any obstructing pedestrians or vehicles. Yet another further extension of this would be to vary the volume of the alarm depending on the distance away the object is from the vehicle.

A third technique is to use broadband sound which is instantly and unambiguously locatable. Sound used in traditional narrowband alarms bounces off reflective surfaces. This could give false directional clues and potentially lead to personal

injuries. Broadband sound (e.g. white noise) is also more environmentally friendly because narrow band alarms produce a tonal noise which is much more annoying to nearby residents. The use of broadband sound could result in an extension of the volume adjustment technique described above where the ambient noise level is sampled in frequency bands and the sound spectrum of the alarm is adjusted accordingly.

There are a number of these types of self-adjusting reversing alarms on the market today. One of the most famous manufacturers of these types of alarms is Brigade Electronics Plc (Brigade Electronics Plc).

## 2.2 Use of EM concepts

Perhaps the most interesting aspect of the EM approach in this context is the ability to experiment with the model in order to intuitively establish beliefs as to the functions and abilities of the “smarter” reversing alarm.

In this way, EM lends itself easily to experimenting with models based on the real world. Definition of observables, which are features of a situation or domain, in this case the domain of a reversing alarm and dependencies between these observables, means that changes to observables can cause changes to other observables and the development of the model can be done with extensibility in mind. Another concept is that of agents: entities within the domain perceived as capable of initiating state-change. In this case, there are two main agents: the driver of the reversing vehicle and a pedestrian obstructing the path the vehicle is taking. A third agent could be considered to be the ambient noise, which is in fact a combination of state-change by a number of other agents such as passing cars or residents. For the purposes of this EM model, however, this agent is abstracted to be a randomly changing observable, “ambient noise” which normally takes values between 35 and 45dB, which is representative of normal ambient noise levels.

It is worth noting that this notion of agency within the model evolved with the construal. Initially, only the reversing alarm was modelled. Further work on the model was done to add the pedestrian and ambient noise level. Dependencies between the observables include the dependency for the alarm to be 10dB above the ambient noise level, and the dependency for the frequency of the alarm to change with respect to the distance from the obstructing object. This leads appropriately to some assumptions to be made in order to simplify the scenario and make the construction of an EM model possible.

## 2.3 Assumptions and abstractions

In order to use EM techniques and provide a working model with time constraints, a number of assumptions must be made. Firstly, exact distances are not used within the model for the size of the vehicle, which is chosen to be a lorry, and the pedestrian. Both the lorry and the pedestrian are very simplified and are depicted by a rectangle and a circle respectively. As aforementioned, the ambient noise level is abstracted from several sources to being one source which randomly changes between 35dB and 45dB.

Another abstraction is that of the lorry needing to sense the obstructing object. This is no simple task, and requires complex hardware and software. However, for the purposes of this EM model, it “just works”. Similarly, the model assumes that the alarm uses broadband sound (e.g. white noise). Broadband sound is instantly and unambiguously locatable. Sound used in traditional narrowband alarms bounces off reflective surfaces. This could give false directional clues and potentially lead to personal injuries. Broadband sound (e.g. white noise) is also more environmentally friendly because narrow band alarms produce a tonal noise which is much more annoying to nearby residents.

## 3 A detailed look at the EM model

This section gives a detailed look into the EM model developed in order to investigate “smart” reversing alarms. The model can be viewed by running the file `reversingalarm.e` in `tkeden`. In developing the EM model, a number of previously constructed models were used in research including Room viewer (Yung, 1991), Traffic Light (Mendis, 1997) and Scout Examples (Wong, 2000).

### 3.1 An LSD specification

Although an LSD specification was not formally written prior to development of the EM model, it is very useful to classify the observables within the system using the special-purpose LSD notation. Within an LSD account, the state-changing agents of the system are identified.

For the reversing alarm scenario, the two agents, as already mentioned, are the reversing vehicle and the obstructing object (pedestrian). In an LSD specification, the observables in the scenario are classified as state, oracle or handle observables<sup>1</sup>.

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<sup>1</sup> LSD Notation:

<http://www2.warwick.ac.uk/fac/sci/dcs/research/em/intro/glossary/#lsdnot>

State observables of the reversing vehicle include the vehicle itself, the detector, and the position of the vehicle. Oracles are the detector which detects where the obstructing object is. Handles of the vehicle include the speed of the vehicle, the alarm volume and the reversing light, as well as the position of the vehicle.

State observables of the pedestrian are the pedestrian itself as well as its position. Oracles should include some observables of vision and hearing but in this model there are no such observables. Handles of the pedestrian are its position.

### 3.2 Use of EM notations

In developing the EM model, the EDEN, DoNaLD and SCOUT notations are used extensively.

EDEN, which stands for the Engine of Definitive Notations, is the primary tool of use for building EM models. EDEN implements a variety of notations, which includes DoNaLD and SCOUT.

DoNaLD (Definitive Notation for Line Drawing) enables the development of 2D graphics within the EDEN environment. DoNaLD is used in order to develop the EM model to be visual and make use of coordinates for placement of objects. The lorry is a rectangle built within DoNaLD and the pedestrian is a circle. DoNaLD allows the abstraction of these shapes and builds the underlying EDEN definitions necessary.

SCOUT, the definitive notation for Screenshot Layout, is used to enable interaction within the model. This includes the various buttons for triggering definitions.

### 3.3 The model in action

Figure 1 shows the reversing alarm EM model in action. It can be seen that, in this initial state, the alarm volume is zero: effectively the alarm is off. Ambient noise fluctuates and this is done using the `randomise()` function within EDEN. There is extensive use of `edenlocks` in order to enable the lorry to move and the ambient noise to fluctuate.

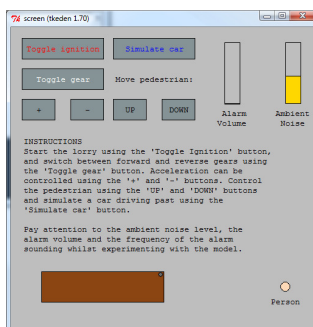


Figure 1: Reversing alarm EM model

Figure 2 shows a different state of the model, where the lorry is moving towards to the pedestrian, and the alarm is sounding.

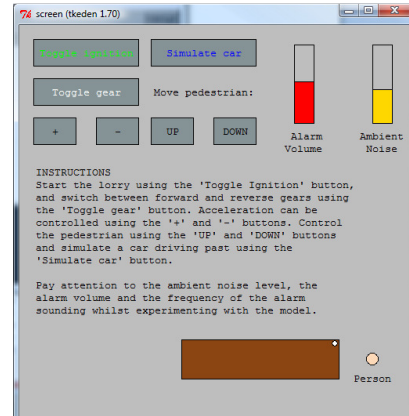


Figure 2: Vehicle reversing with alarm sounding

The alarm is sounded in three stages. The first warning is a slow beep, the second is an urgent beeping and the final stage is a constant tone. Detection of the person is done by using an invisible DoNaLD circle representing the detector behind the lorry, and the use of the function `inside()` to test whether the centre coordinate of the person is within the circle. One interesting observation is to show the detector, which can be done by running the EDEN command `showDetector = 1;` in the command line interface.

In addition to controlling the lorry and the pedestrian through the controls at the top of the screen, a simulation of a car driving past can be made by clicking the “Simulate car” button. This increases the ambient noise level for a specific duration, to simulate the increase in ambient noise as a result of the car driving past. This is a trivial example and can be applied as an example of a plane going overhead or other changes to ambient noise. Figure 3 shows the increase in ambient noise and hence alarm volume as a result of the simulation of a car driving past.

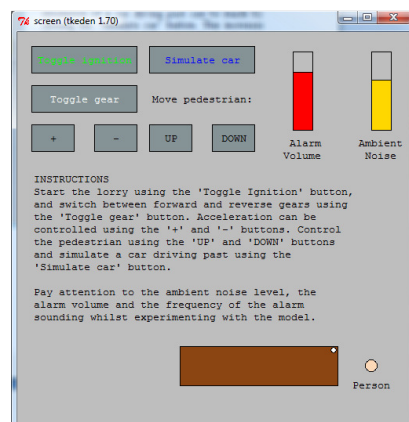


Figure 3: Increased ambient noise as a result of a passing car, and the alarm volume increased appropriately

## 4 The potential for use as an educational tool

There is a great potential for this EM model to be used as an educational tool. Users could experiment with the model to learn more about why accidents occur when vehicles are reversing, and how a “smart” reversing alarm such as the one modelled can reduce the numbers of accidents. A number of additional possible extensions relating to increasing the effectiveness of the model in a learning environment are detailed in section 5.2.

## 5 Evaluation

This section outlines the evaluation of the EM model in three areas. Firstly, an overall evaluation of the EM model with respect to how well it achieves the goal of modelling a “smart” reversing alarm. Secondly, the possible extensions to the EM model are detailed. Finally, the EM approach is compared with other, more conventional, approaches to the task.

### 5.1 Evaluation of the EM model

The EM model built is solid and provides a great way to learn about and experiment with the advanced reversing alarm techniques. The criticisms of the EM model would be that it oversimplifies the scenario; however this has already been outlined as a necessity, and could be worked on in the future with this paper as a solid foundation.

### 5.2 Possible extensions to the EM model

There are a number of possible extensions to the EM model, and these fall roughly into two categories. Firstly, there are extensions to functionality of the reversing alarm. Secondly, there are extensions to the EM model in order to make it more effective. “Effective” in this context is used to mean either increased accuracy or correctness of the model or increased value of the EM model as a learning tool.

#### 5.2.1 Extensions to the functionality of the reversing alarm

There are a number of ways in which the EM model could be extended to incorporate additional useful functionality of a “smart” reversing alarm.

- Model individual frequency bands of the ambient noise and match the alarm sound to the frequency bands. This would show that the output of the alarm does not have a significant peak in a band and lower in other bands, as would be the case with traditional narrowband alarm systems.
- The addition of a fail-safe mechanism where the system then fall back into a simple alarm system if a failure occurred.

#### 5.2.2 Extensions to the EM model in order to make it more effective

Some possible extensions are identified to add more value to this EM model for use as a teaching tool.

- Separate windows as well as the existing top down view to enable the user to see the perspective of the driver and the pedestrian.
- Actual output of sound.
- More complex modelling of the ambient noise.

### 5.3 EM approach in comparison to conventional approaches

The varied tools available in order to take an Empirical Modelling approach provides an interesting alternative to traditional computer science methods to solve a problem such as this one.

Dependency is clearly a very powerful concept which can be utilised to reduce the effort required in maintaining synchronisation between observables.

Conventional approaches such as Object Oriented Programming provide good ways to modularise code and increase code maintenance, and this may be the area where the EM approach needs work. Maintainability and scalability are the areas in which EM may not be able to perform as well as other approaches, and most models developed using the EM approach thus far are relatively simple.

In conclusion, however, EM has proved to be a very good approach in order to build a model of a “smart” reversing alarm with many aspects of functionality in a fairly short period of time.

## 6 Conclusions

It has been shown that EM can be used as a powerful tool in modelling a real world scenario such as that of a “smart” reversing alarm. EM model development frees the modeller from having to think about coding issues such as maintaining consistency between observables.

## Acknowledgements

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