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Optimising police dispatch for incident response in real time

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ABSTRACT

It is crucial that police forces operate in a cost efficient manner and, in the case of incident response, that the most efficient resources are allocated. The current procedure is that police response units are allocated manually by a dispatcher using a resource list and mapping software. The efficiency of this process can be improved by the use of integrated mathematical approaches embedded within an automatic framework, yielding the optimal selection framework developed in this paper. The framework combines mapping and routing algorithms, and a decision process to facilitate optimal officer selection for incident response. The decision process considers information such as quickest response time, predicted traffic conditions, driving qualifications, response unit availability and demand coverage. The selection framework has been tested and validated through simulation and has shown to increase the efficiency of response units through reduced response times, increased response unit availability, and greater demand coverage.

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Allocation; decision support systems; police incident response; simulation; vehicle routing

1. Introduction

Police forces are continuously looking for new methods of improving efficiency. This is especially true with UK forces due to the funding cuts they are currently facing. One area in which it is believed that efficiency could be improved is the incident response process. Generally incidents that are reported to the police in the UK are classified into four grades. The most serious, where there is a threat to life or risk of serious injury, are classified as grade 1, and in this case response is required typically within 15 min in city areas and 20 min in rural areas. Grade 2 incidents are priority situations, where for example vulnerable people are involved. Response is not so urgent but still has a time limit, such as one hour for Leicestershire police. Grades 3 and 4 are incidents that can be resolved by scheduled appointments. Once a grade 1 or 2 incident has been reported to the police, a response unit is sent to attend it. Such a unit consists of a police vehicle that could contain one or more police officers. The current process of selecting a response unit to attend an incident is generally carried out by a dispatcher using a map, showing the incident location and response unit locations, along with a resource list detailing response unit statuses. The dispatcher should then pick the most appropriate unit to attend, however they often do not feel the information they have is adequate to make an informed decision. Hence, it is often the

case that dispatchers will place a blanket call out to all units enquiring who can attend and making the decision that way. This does not always lead to the most efficient response unit being chosen.

As it is crucial for the public that incidents classed as grade 1 and 2 are responded to quickly and efficiently, it is important that the dispatcher is able to make an informed and timely decision on who to allocate. Hence in this research a computer-aided dispatch tool, encompassing several integrated algorithms, has been developed to take all the information available and use this to make an informed decision on which response unit is most appropriate to send to an incident. The decision framework developed takes into account the availability of units, their predicted response times and the driving qualifications of the officers in the unit. The effect on the coverage provided by the police in high-demand areas through units being allocated and hence removed from their current position, known as demand coverage, is also taken into account. This extensive combination of factors to dispatch police has not been performed before. The outcome is a list ranking response units from most efficient to least efficient displayed to the dispatcher. This will give dispatchers more confidence in making a decision and help utilise resources more efficiently.

The decision framework is enabled through integration of three main elements; mapping algorithms, integrated with weighted routing techniques, all embedded

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within a decision process. The mapping functionality details the road layout within the region under the police force's control. It also allows response units and incident locations to be plotted. The routing technique determines the quickest route from a response unit to an incident. The decision process considers the selection criteria to determine which response unit is the most efficient.

In order to validate the optimised selection process developed and test its efficiency without carrying out field tests, discrete event simulation has been performed. Carrying out field experiments is rare due to the high costs involved and risks if something goes wrong (Liu & Eck, 2008). The simulation runs through typical situations and finds the most appropriate unit to send using the algorithm developed, recording information such as incident response times, availability and driving distances to incidents. These results are compared with the selection of officers in the absence of the decision tool which is represented by narrowing down the selection to the four closest officers and then randomly choosing from these response units. This is taken to represent the current situation, referred to previously, where dispatchers are working with a combination of information on officer location and officers volunteering to attend incidents. The selection framework has been developed with the collaboration of Leicestershire Police in the UK and hence in the simulation Leicestershire has been used as the case study. Results may vary for other areas.

In this paper, relevant past research will be explored in the section 'Background to Dispatch'. The section on 'Incident Severity and the Decision Process' and the section on 'Factors Affecting the Decision Criteria' outline the decision process for selecting a response unit. The algorithm to implement this process is given in the section 'Selection Process Overview'. The simulation used to test the processes is then detailed in the section titled 'Simulation' and the results discussed in the section titled 'Results'. Conclusions and future work are discussed in the final section.

2. Background to dispatch

Research into police dispatch is limited however relevant work exists in other services including the ambulance service, fire engines and taxis. Police dispatch often considers the effect on queuing (Green, 1984). A multi-server queuing system with multi-priorities is used to model patrol car operations. The purpose of this method is to provide a more accurate basis for the efficient allocation of patrol cars, to estimate queue times. This study uses the dated practice of segregating precincts into separate geographical areas which operate individually. In the queuing process, each server is considered identical and calls for service arrive according to a Poisson process at rate λ . Two priority classes are considered, similar to emergency and priority response

discussed in the model developed within this paper. The emergency class is served ahead of the priority class but within each class the situations are served on a first-come first-served basis. The algorithm proved useful as a decision tool in policies such as having single-crewed patrol cars, by analysing the average number of available servers and the fraction of emergency calls which have a positive delay. (Guedes, Furtado, & Pequeno, 2015) developed a multi-objective algorithm for optimising police dispatch in Brazil. The model looks into incident queuing to minimise incident wait time and cost whilst also maximising the attendance to priority incidents. This is achieved through the development of a multi-objective evolutionary algorithm. The queuing system considers spatial allocation and dispatch policies to order the queue. Considering spatial allocation ensures areas with high crime rates have more officers present than areas with lower crime rates. Multi-agent simulation is used to obtain results, where each police patrol car is considered as an agent.

More research work has been carried out in the area of ambulance dispatch and positioning. An ambulance dispatch tool, produced by (Haghani, Hu, & Tian, 2003), includes a queuing system to prioritise more severe incidents, a relocation ability and real time traffic information. This approach is well suited for the ambulance dispatch problem but does not address the specific issues required by a police dispatch algorithm such as demand coverage. Also (Henderson & Mason, 2004) provided an ambulance dispatch tool with the addition of a positioning tool for ambulances and ambulance stations. The resulting programme, BARTSIM, was tested using simulation and through implementation into an Australian ambulance service. The paper concluded that no off-the-shelf product was available to make the decisions required. A positioning tool, such as that developed by Henderson and Mason, is suitable for ambulance location modelling because they are not required to be visible. However, it is a requirement on the police to be visible to the public in order to deter crime and hence they must have dynamic positions. A recent study, (Bandara, Mayorga, & McLay, 2014), noted that most ambulance location models involve the rule of dispatching the closest ambulance available to the incident irrespective of the incident severity. It was also noted that this method is not always optimal for minimising average response times (Carter, Chaiken, & Ignall, 1972). It suggested that the severity of the incident and the effects on demand coverage should be factors considered when selecting the appropriate ambulance to assign to an incident. In this case, demand coverage refers to the number of demand points that can be covered within the set response time. A dispatch algorithm was produced which took into account response times, severity of incident and the effect on demand coverage. These factors are similar to some of those necessary within a

police dispatch selection framework though the criteria on which they are based will differ.

Studies into fire service dispatch are sparse. A study by (Ignall, Carter, & Rider, 1982) carried out on the fire service dispatch process looked into increasing the second fire engine response time when a severe incident occurs requiring more than one fire engine. The study uses historical data to predict how many fire engines are required to attend an incident. Simulation is then used to test the effects of this new process which revealed a decrease in response time of the second fire engine.

Other relevant work into dispatch includes the dispatch of taxis. In some cities, such as Singapore, taxi usage is very popular leading to many taxi companies competing for business. To be competitive, dispatch planning is required and hence extensive research has been undertaken in order to maximise dispatch efficiency. (Kiam Tian Seow, Nam Hai Dang, & Der-Hong Lee, 2010) developed an algorithm to optimise taxi response time by considering global taxi dispatch efficiency rather than local efficiency. This involves not dispatching on a first-come first-serve basis but considering those taxi requests which come in within a time window concurrently. By looking at the group of taxi requests collectively, the group efficiency is optimised and hence the overall efficiency is increased. In this case, efficiency is measured in the time it takes a taxi to reach the customer. The location of the taxis is tracked using GPS and geographical and traffic information is used. Although the problem of taxi dispatch does have similarities with police dispatch, there are major differences. The taxis negotiate for the jobs whereas, for the police, quick decisions must be made taking into account many other considerations.

Given the necessity to include mapping the region of interest and routing officers to incidents within the selection framework past work in these areas has been considered. It was shown by (Geisberger, Sanders, Schultes, & Delling, 2008) that the road network of a region can be plotted as a directed graph. Road weightings have been used to predict routes in various applications, one being timber haulage (Devlin, McDonnell, & Ward, 2008). Timber haulage requires careful route planning to prepare for the harvesting season ahead. The research performed route calculations using road weightings assigned to each road type whilst performing Dijkstra's algorithm. The weighting system was used in order to ensure that the route selected roads with the highest classification, for example a motorway over a residential road, rather than using distance. The combination of directed graphs and weighted Dijkstra's algorithm will be utilised in this research, albeit in a different way, in order to pick the quickest route over the shortest route to find the optimal officer.

A study by (Adler, Hakkert, Kornbluth, Raviv, & Sher, 2014) deals with the location and allocation of traffic

police patrol vehicles. The positioning is determined using variations of the set covering problem and maximum coverage location problem. Their method divides the road network up into regions and each officer is allocated a region. When an incident occurs, this is allocated to the officer in control of that region. Another study on emergency service response (Araz, Selim, & Ozkarahan, 2007) uses a fuzzy multi-objective covering-based vehicle location model to position ambulances and firefighting systems. There are many studies on positioning of emergency resources. This police allocation model developed here considers demand coverage when tasking officers with incidents. It does not position officers. A study relevant to police response is that by (Zipkin, Short, & Bertozzi, 2014) which looks at crime mapping and how to target high crime areas with police patrols. The study is on actual crime levels and demonstrates that targeting high crime areas reduces overall crime but also displaces some crime. The displaced crime must also be targeted with police patrols.

The optimal selection framework developed in this research work makes decisions based specifically on the needs of the police. An algorithm has been developed, which includes all the comprehensive factors necessary to make an informed decision, which has previously been lacking. A decision process like this is not currently available to the police force but is necessary to ensure response resources are used more efficiently.

3. Incident severity and the decision process

The decision as to who to send to an incident should lie with the dispatcher and not the response units. The output from the optimal selection framework is to advise dispatchers on which response units are the most appropriate to assign to an incident. Not only would this result in more informed decisions but it also gives the dispatcher more confidence to assign resources and the response units more confidence that they are the best unit to attend the incident.

Officer selection is required when a timely response is required, for incidents identified as grade 1 or 2. The decision process varies depending on the incident severity due to the different time constraints. Figure 1 shows the factors considered for the two different decision processes, which have been developed in this work, depending on whether the incident is an emergency or priority incident. In Figure 1(a) the process is shown for an emergency incident, grade 1. In this case, the process considers response units' availability and the predicted response time taking into account current traffic and driving standard. In Figure 1(b) the process is shown for a priority situation, grade 2. In this case the process considers availability, taking into account response units which are not immediately available but will become available in the appropriate time, and the predicted response time taking into account current

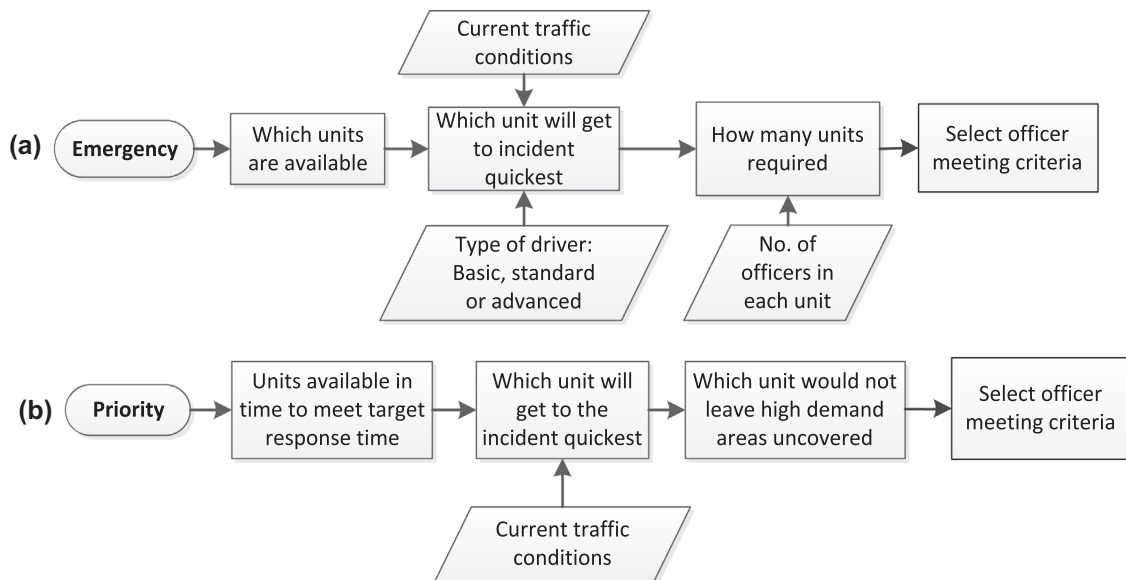


Figure 1. Factors considered in the decision process (a) emergency (b) priority.

traffic conditions and the effects moving a response unit has on demand coverage.

Incidents are not to be dealt with in the order they arrive. They are prioritised depending on severity and time and put in a queue. In general, emergency incidents are prioritised over priority incidents. However, if the time in the queue for a priority incident is getting close to the recommended response time for such an incident, emergency incidents are no longer prioritised over it. This works by forming two separate queues. The first queue contains emergency incidents and the second queue contains priority incidents. The first queue is dealt with initially and then the second queue. Priority incidents are upgraded from the second queue to the back of the first queue when the incident's time in the queue nears the end of the recommended response time period of 60 min. This queueing time at which the priority incidents are upgraded is taken to be 45 min as at this point the incident has 15 minutes, to be responded to, before it exceeds the target response time, which is the same as emergency city incidents.

4. Factors affecting the decision criteria

As shown in Figure 1, the decision process requires knowledge of a unit's availability. A resource list is available which lists each unit's status. These describe what the officers within the unit are doing at the time, for example, available, attending incident, on route to incident, paper work and break, etc. These are updated by the officers and hence are dependent on them keeping them up-to-date. The available status means that the unit is available to send to an incident and this is the only status considered in the emergency decision process, Figure 1(a). For priority response, it is possible to utilise resources which are not currently available but will be within a time scale allowing the response time limit to

be met. These resources have statuses such as on a break. The current statuses and the length of time units have been on this status can be used to determine which units will be available in time. Once a unit has been sent to an incident, their status will be updated and hence they will be removed from the potential response units available for future incidents, speeding up the selection process.

There are multiple factors that influence the time taken for a response unit to get to an incident. For example, the distance between the unit's location and the location of the incident, the types of roads between the two locations, the traffic conditions and the officer's driving standard. In order to determine the time taken to get to the incident, mapping and routing algorithms have been used to determine the fastest route. To take into account, the factors that affect the time taken to travel road weightings have been adopted. In the case of types of roads, a weighting is applied depending on the speed limit imposed on that road. The higher the speed limit, the lower the weighting, as these will be the preferred roads. So, for example, a motorway with a speed limit of 70mph will have a lower weighting than a residential road with a speed limit of 20 or 30mph. Traffic conditions vary daily and also by times of day. In the model developed, higher weightings are given to peak days and times known from historical traffic data.

Police officers have varying levels of driver training. At the basic level, an officer is able to drive a police car but is not able to activate the blue lights and sirens. At standard level, the officer is able to use the blue lights and sirens and hence exceed the speed limit if necessary and to drive through traffic lights when they are red. The advanced level allows the pursuit of vehicles failing to stop. In the model, these different levels are considered when allocating response units to an emergency incident where standard and advanced levels may be required. As basic drivers are unable to exceed the speed limit,

they may take longer to get to the incident. This is factored into the model by adjusting weights in the route calculation. Weightings are also given to officers travelling on foot or bicycle, based on the speed officers are expected to walk or cycle. Walking is only permitted on paths and cycling is not permitted on primary roads and motorways. This is achieved by making certain roads unavailable to officers on foot or bike.

Leaving areas of high incident level without a response unit presence should be avoided. In an emergency situation, a quick response overrides the requirement to maintain high-demand coverage and hence is not a consideration in the decision process in this case. However, in a priority situation, the required response time allows maintaining high-demand coverage to be factored into the decision process. Hence, when selecting a response unit for a priority incident response, the change in demand coverage created by sending the response unit to the incident is considered. This involves considering predicted demand in the area and units available to cover it. The decision process will choose response units from where there is a higher coverage level to attend an incident rather than removing a response unit from an area leaving it uncovered. To determine the predicted demand in each area, historical crime data for emergency and priority incidents are used.

5. Selection process overview

In order to implement the decision process shown in Figure 1, it is necessary to automate the procedure of determining the time for units to attend an incident. To do this a map of the area, plotting all roads and paths that response units can travel on, must be generated and then the routes between the units and the incident determined. The full steps of the algorithm are shown in Figure 2.

The algorithm steps are:

- (1) A map is generated for the area.
- (2) For any incident, routes from the n closest units are calculated. The route times are calculated taking into account the factors discussed in the previous section.
- (3) This information is fed into the decision process described in the section Incident severity and the Decision Process and shown in Figure 1, which together with unit availability information and incident grading leads to the ranking of units to select.

Step 1: Map Generation—A mapping application is used in order to detail possible roads to travel on and information such as type of roads, as well as to locate response units and incidents. The road details are taken from (Open Street Maps & Contributors, 2014). This contains information such as points on a road (nodes), the types of roads joining them and traffic restrictions, such as one-way roads. Unnecessary information has been removed by filtering. The map is formed using a directed graph, Equation (1).

$$G = (V, A) \tag{1}$$

where V is a group of vertices, which represent the longitude and latitude points along a road and A is a set of arcs joining these vertices. The graph is directed as some roads are only available to travel on in one direction. Figure 3 shows the resulting graph for the Leicestershire area as an example (different shades reflect different road types). The details of each road, e.g., road type, length and one way system are kept in a matrix for future use in the routing process.

Step 2: Route Generation—Routing is required to determine the fastest route between a response unit and an incident. This is necessary in order to determine which response unit has the quickest route to the incident. For the routing process, the response unit locations are taken from GPS data and the incident location requires an input from another programme or from a dispatcher, using the information received about the incident.

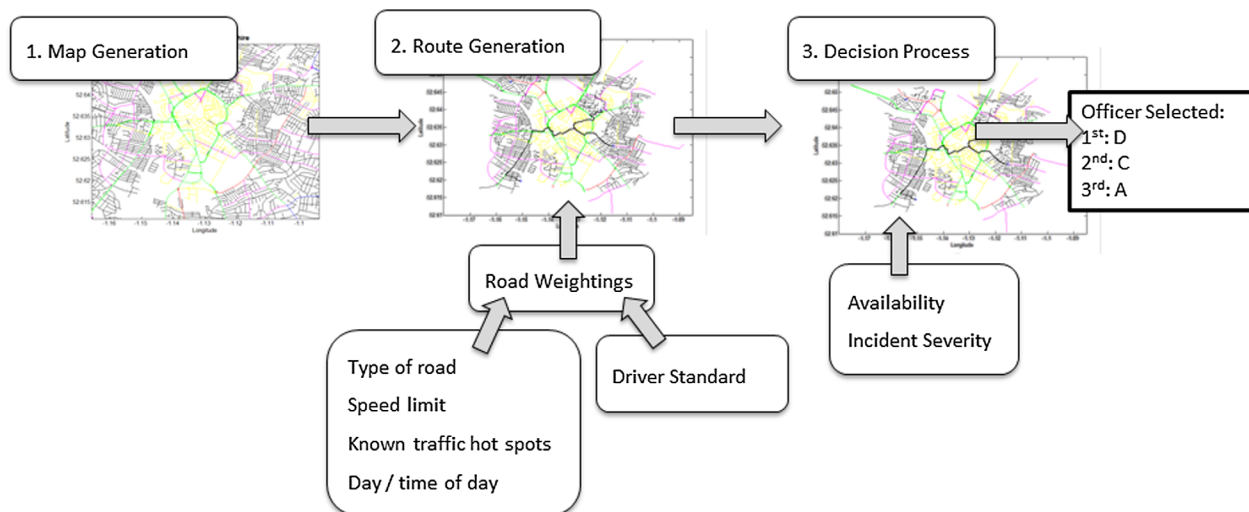


Figure 2. Dispatch decision algorithm.

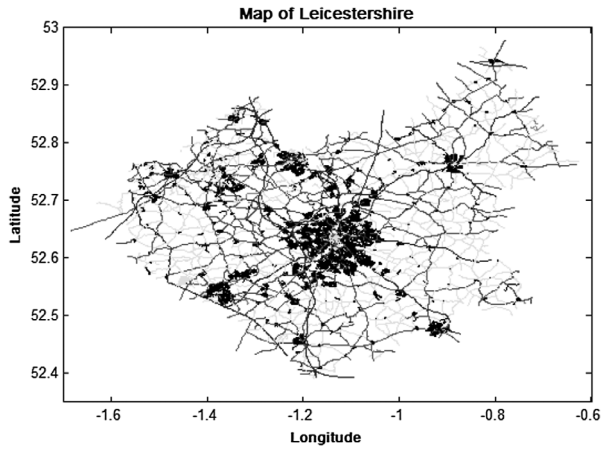


Figure 3. Road map of Leicestershire.

It is imperative that police dispatchers have access to a programme that gives results fast. Therefore when determining the fastest routes between officers and an incident, in order to save computational time, not all response units are considered. Instead the routes between the incident and the n closest officers to it are determined, where n is an integer whose value is dependent on where the incident occurs. In city centres n will take a larger value than in rural areas, as in a city centre there is typically less distance between response units than in rural areas. The n closest response units are determined using the straight-line distance between the response unit and the incident. The exact route is then calculated for those n response units using Dijkstra's algorithm. This algorithm is commonly used to determine the exact shortest path between two points (Beasley, 1983; Joyner, Nguyen, & Cohen, 2011). It has been chosen in this application as it obtains the exact shortest path and it is easy to use. Hence a path is calculated from each unit's location to the incident. The total distance travelled on the path is the sum of the distances travelled along each road which makes up the path. As mentioned previously, there are many factors that influence the time taken to travel along a path and hence the closest unit may not necessarily be the quickest to reach the incident. However, taking into account these factors using weightings, as described earlier, the cost of the route can be expressed in terms of road weightings and path taken. In order to determine the fastest route, it is necessary to minimise this cost. Hence, the problem reduces to Equation (2).

$$\min \sum_K \sum_{i,j} W_K(t) D_{K_{ij}} \quad (2)$$

where $W_K(t)$ is the weighting of road K , which is dependent on time t . $D_{K_{ij}}$ is the distance travelled between nodes i and j on road K . This equation calculates the sum of the cost of travelling on each section of road and the sum of the total cost of the journey and seeks a path which minimises this cost.

Step 3: Decision Process (Weightings)—The speed which it takes a vehicle to travel on a road is determined by the road weighting. The road weightings change depending on:

- type of road,
- type of incident,
- driving qualification,
- day/time of day (traffic).

The road type determines the speed limit. The incident type determines whether lights and sirens can be used and hence changes the speed at which the response units can travel. The driving qualification also determines whether lights and sirens can be used as only those with a qualification above basic can use them. The day and time of day determines the traffic. There are two categories for traffic, peak and non-peak, the speed on a road at peak times and non-peak times are determined using historical traffic data for that area as are the times at which peak, and non-peak, traffic are assumed to occur. The selection framework decides which road weightings to use based on these factors by following the decision tree in figure 4 which leads to four different weighting systems.

Under each of the four categories, the weightings for each road are listed in Table 1. These are determined using historical traffic information from Leicestershire to predict the speed cars can travel on different types of road. The speed of 30 miles per hour is assigned to the weighting 1 and the rest are assigned accordingly. An example of optimal route generation is shown in Figure 5. The cross shows the location of an emergency incident whilst the circles, labelled A, B, C, and D, show the location of the four closest available response units. Table 2 shows the costs of routing in this case for the four units. As can be seen from the table, although unit A appears the closest to the incident, when taking into account the factors that affect the speed of response, unit C is the most efficient to dispatch.

At this point in the algorithm, priority incidents are dealt with differently to emergency incidents as in priority situations the demand coverage is considered. To determine the effect on the ability for police to cover future incidents caused by moving each of the officers in consideration to the incident location, the demand coverage in each scenario is calculated. This is done by calculating the predicted demand level in each region by laying a square-celled grid over the map and calculating the average number of incidents which occurred within the grid cell in the relevant time period using historical data. The demand coverage is then calculated using a variation of the equation used to calculate coverage in the maximum coverage location problem. The maximum coverage location problem has been used in ambulance positioning by papers such as that by (Gendreau, Laporte, & Semet, 1997). The equation used to find the demand coverage in this problem is found in Equation (3). The equation analyses each demand point v_i in a set of demand points, V , to determine if it is considered covered by the appropriate number of resources. The equation sums together the demand of all the demand nodes, which are considered covered by the appropriate number of resources, to find the total demand coverage.

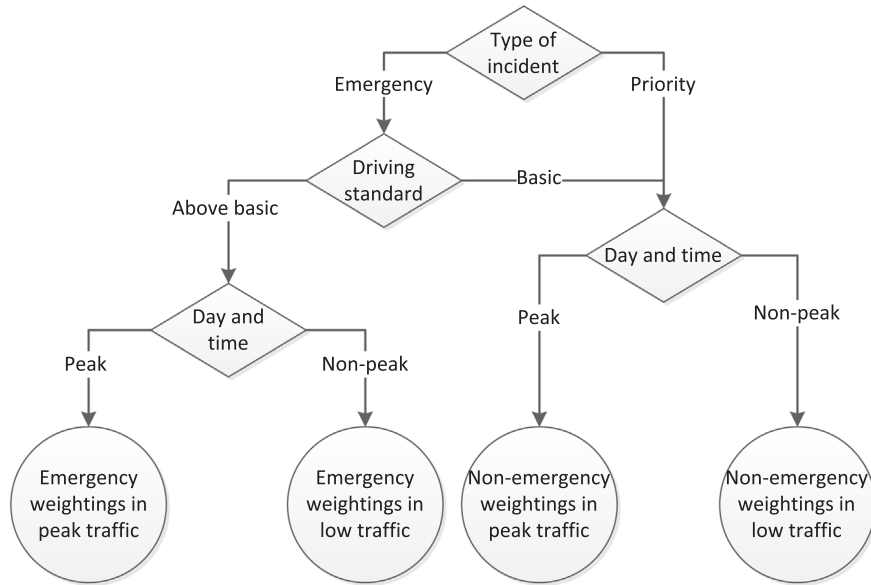


Figure 4. Road weighting selection process.

Table 1. Road weightings.

Road type	Emergency weightings in peak traffic	Emergency weightings in low traffic	Non-emergency weightings in peak traffic	Non-emergency weightings in low traffic
Motorway	0.43	0.33	0.60	0.43
Trunk road	0.43	0.33	0.60	0.43
Primary	0.43	0.33	0.60	0.43
Secondary	0.5	0.38	0.75	0.5
Tertiary	0.75	0.5	1	0.75
Unclassified	0.75	0.60	1	1
Residential	0.75	0.60	1	1

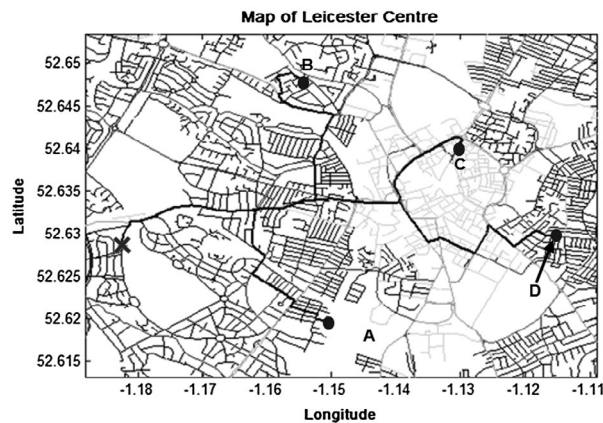


Figure 5. Route from officers to incident.

Table 2. Costs of routing for incident.

Response unit	Routing cost
A	3.27
B	3.79
C	3.21
D	4.59

The demand coverage is calculated for each scenario. $1x_i^k$ and $2x_i^k$ are binary values which equals 1 if the demand point v_i is covered by a minimum of k resources within

the radius r_1 and r_2 where $r_1 = 20$ km and $r_2 = 20$ km, based on the distance each resource is expected to be capable of travelling within the target response times for each region. C and R are also binary values, C equals 1 if the node under consideration is in an urban area and 0 if it is not and R equals 1 if the node under consideration is in a rural area and 0 if it is not. If it is considered covered, then the cell's demand level λ_i is considered covered.

$$\text{Demand coverage} = \sum_{i \in V} \lambda_i 1x_i^k C + \lambda_i 2x_i^k R \quad (3)$$

The resulting coverage when each officer is moved from their current position to the incident location is calculated and this is factored into the decision process by setting a limit the demand coverage cannot fall below, specific to each police force depending on the region. If moving the officer would result in the demand coverage falling below the desired limit, they will not be considered in the allocation process. If none of the officers can be moved due to demand coverage, the simulation will wait to assign a resource to the incident until the appropriate level of demand coverage can be maintained or the incident is nearing the limit of the response time permitted to attend the incident.

6. Simulation

In order to test and validate the selection framework, discrete event simulation has been used. This allows the effectiveness of the algorithm to be analysed without compromising the dispatch process. Historical data have been used to model demand and hence test under realistic conditions.

The process of the simulation is outlined in Figure 6. Initially a map is generated for the area of concern. A random historical 24-hour time period is selected for use in testing from the available data. The incident data used are historical data from Leicestershire police. The

incidents which occur during the selected time period are input into the simulation as they arise. The information each incident carries, such as the location and severity, is then used, along with the available response unit information, in the dispatch decision framework to analyse which response unit will be the most appropriate resource to send, as detailed in the previous section. The decision path followed is based on the severity of the grade of the incident. A list of units to send to the incident, ranked in order with the most appropriate ranked first, is produced. The simulation then selects the resources required from the top of the list and updates the resource list accordingly. The time the response unit then remains in the unavailable status is determined by the historical incident data for that type of incident. The historical data have been analysed to give normal distributions for the time spent at each type of incident. During the simulation, the type of incident is given and the duration of time spent at this incident is determined from the distribution. The results collected by the simulation are; the response times, the total time response units are available and distance travelled to incidents. These all allow the efficiency of the approach in the algorithm developed to be analysed. The simulation is run for 100 time periods and the results are averaged to gain a more accurate idea of the effects.

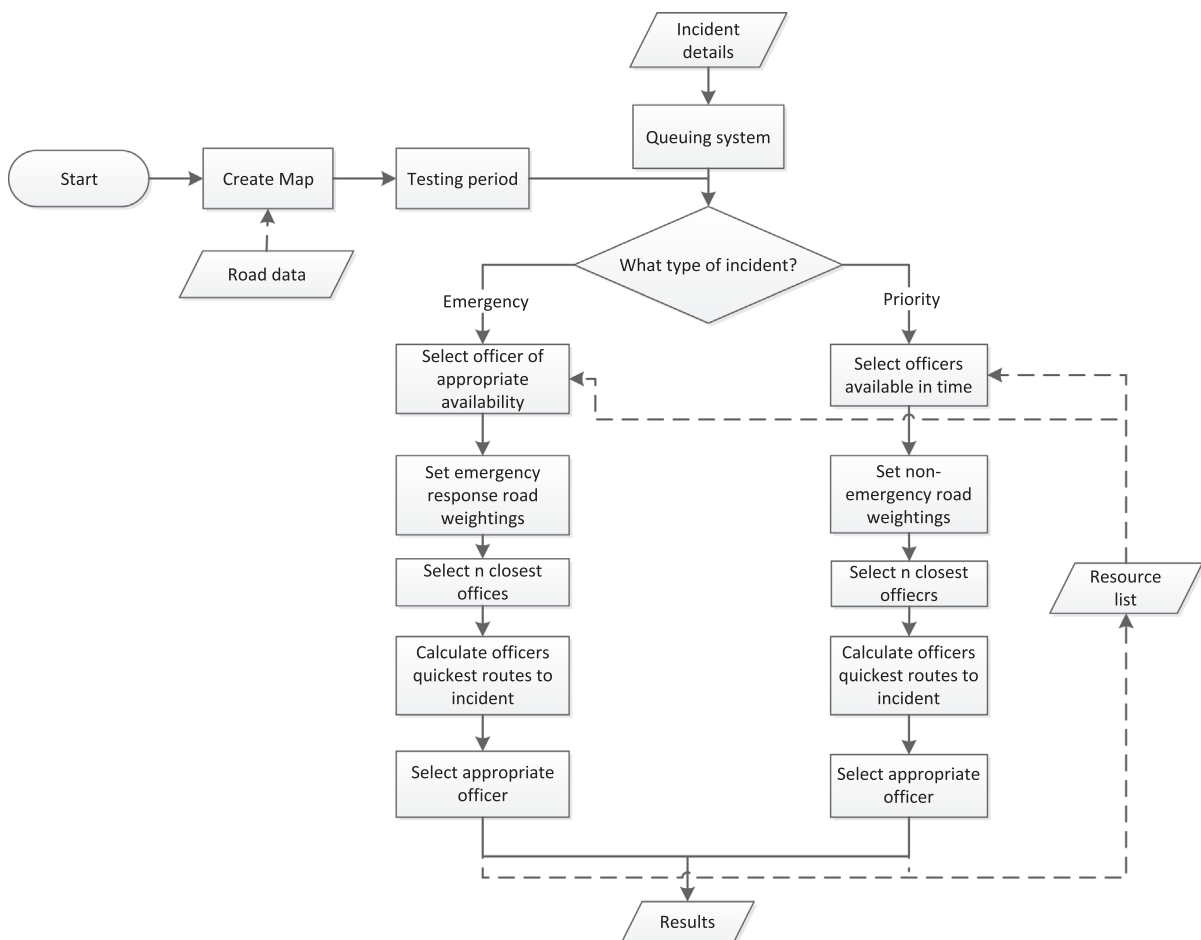


Figure 6. Simulation process.

In order to determine how effective the output is, another simulation is run as a comparison which uses the same crime data but the response unit sent to the incident is selected by narrowing the options down to the four closest officers and choosing randomly from these four officers. This is to simulate the culture of asking for resource rather than assigning them. The four closest officers are determined using the straight line distance between the officers and the incident. Comparing the efficiency of this method with the use of the dispatch framework will show the difference appropriate selection can make to resource efficiency. It is possible that the dispatcher will use some information to guide their decision and hence the selection of the response unit would not be entirely random. In that case, the comparison of the efficiency of the method proposed with that adopted will be less than shown in the results below.

7. Results

The simulation was run for Leicestershire with staffing levels based on those typically available to Leicestershire police. The incident information used in the simulation was randomly selected from historical data dating back two years. These data included a mixture of grade 1 and grade 2 incidents. Initially, the number of officers to be selected for routing to an incident, n , is investigated to determine the optimal number to use for the rest of the simulations. To find the optimal number, the average route cost is found for each n used and compared to the average computational time. The results of this are presented in Figure 7 and 8. Increasing n increases the chance of the optimal officer being chosen but also increases the computational time. The computational time increases substantially as more officers require routing and this is the most time consuming section of the programme. From the graphs, it can be seen that routing more than four of the closest officers does not

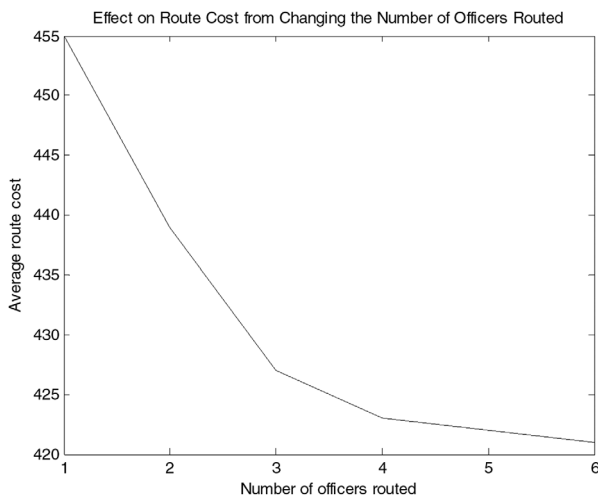


Figure 7. Graph showing the effect on route cost from changing the number of closest officers to route to the incident.

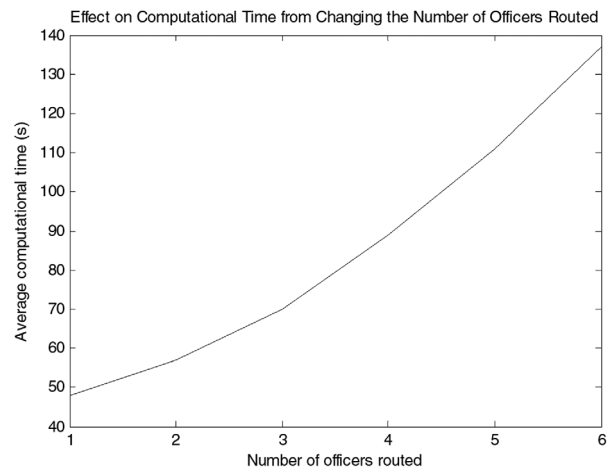


Figure 8. Graph showing the effect on time from changing the number of closest officers to route to the incident.

result in significant changes in the routing costs, though it does result in significant time increases. Any less than four officers and there is a significant difference in routing costs. Hence, for the rest of the analysis four officers are used. This analysis should be performed in each region which it is being used to find the ideal number under the specific police force's constraints.

Considering emergency incidents, Table 3 shows the comparison of average response times along with the minimum and maximum response time for the case where the selection algorithm is used and where random selection out of close proximity officers is used. Over the entire county of Leicestershire, the results show a 28% decrease in emergency response times. This is beneficial to increase public safety, increase the public's satisfaction with the police force and keep to response time guidelines. The simulation also shows a 6% increase in availability due to the decreased time spent travelling to incidents. This is beneficial to give response units more time to patrol and also to give more choice of response units to attend an incident.

The results from the simulation show that using the decision process formed in this study can lead to efficient officer selection with a reduction in response time and an increase in police availability. Using the resource dispatching algorithm means that strategically it is decided that demand coverage will not be heavily compromised to attend a priority incident. The random selection algorithm does not use the demand coverage information to delay sending resources in support of demand coverage. Although using the decision algorithm delays response to priority incidents in some situations, it also results in decreased response times to priority incidents due to the more efficient use of resources for emergency incidents and the maintenance of demand coverage. This meant that 97% of simulated incidents were covered in under the response time targets compared to the 94% covered using the random selection of close proximity resources. Using this algorithm could have

major benefits on response efficiency and help police forces use their resources to their highest potential. As well as using the model for selection, the simulation has also proved useful in seeing how different staffing levels affect the queuing process and response times. Figure 9 shows simulation results run over a small region of Leicestershire, the centre of the largest city in the region, Leicester, for different staffing levels. Figure 9(a) shows the percentage of simulated emergency incidents

Table 3. Response times.

	Selection algorithm	Random selection in close proximity
Average emergency response time (s)	423	586
Minimum emergency response time (s)	30	41
Maximum emergency response time (s)	1472	1891
Percentage of priority incidents attended within response time target	97%	94%

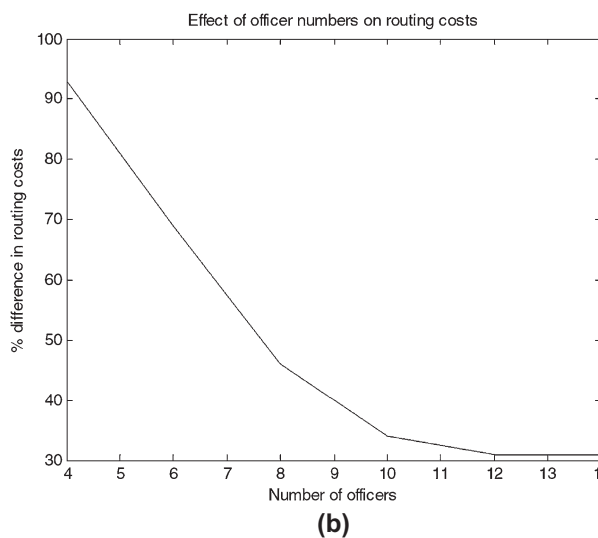
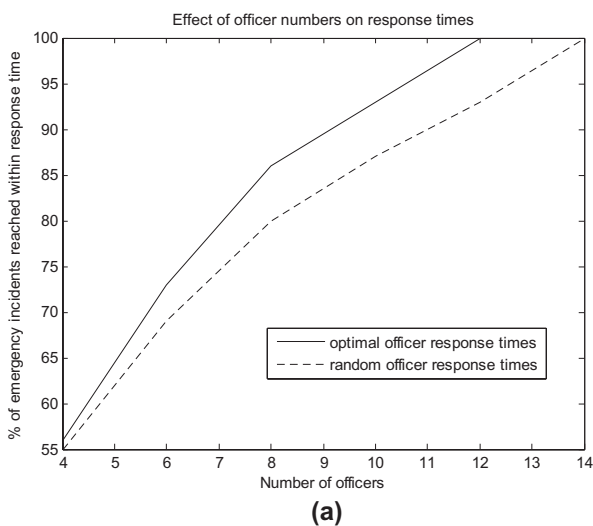


Figure 9. Results for varying staff levels in Leicester city centre, (a) effect of officer numbers on response times, (b) effects of officer numbers on routing costs.

attended within the target response time; the solid line shows the results using the selection algorithm and the dotted line shows the results using random selection out of close proximity officers. As expected, the results show that the percentage of simulated incidents attended within the target time increases as the number of resources available increases. The rate of increase is seen to be faster when using the decision framework over random selection with all incidents being attended within the target time with 12 officers, using the algorithm, but 14 officers are needed if random selection is used. These results show even over a small region, using the methods developed in this work, can result in more efficient use of staff and lower staffing levels required to meet targets. Figure 9(b) shows the percentage difference in the cost between using the decision algorithm and random selection. It can be seen that with low numbers of staff the cost savings through using the decision framework to select the most appropriate officer are large. The saving decreases as the number of staff increases, however even with 12 officers available, when the decision framework results in 100% attendance at emergency incidents within the target time, there is still a 30% saving in using this method.

All results are subject to change depending on regional information used in the simulation. Results vary with factors such as the number of response units on shift, time spent at incidents, and road weightings. The number of response units on shift varies in different police forces. Decreasing the number of response units on duty in the same area will lead to a decrease in available units to send to an incident and this creates a lower chance of making savings but savings can be on a larger scale, as seen in Figure 9. Increasing the number of response units gives a greater choice of response units and hence there is more chance of making efficiency savings through using the selection algorithm but these savings are on a smaller scale. The time taken to deal with incidents is predicted using historical data from Leicestershire police and hence may be different in other police forces. Increasing time taken to deal with incidents decreases the availability of response units, which gives a similar effect as decreasing the number of response units. Decreasing time to deal with incidents has the opposite effect. The road weightings are subject to change depending on the area. Changing the road weightings gives a slight variation in the predicted response times.

8. Conclusions

There is a significant need for improvements to the current police dispatch process. Current methods lead to uninformed decisions. The factors considered by the decision algorithm developed here allow a more informed decision to be made leading to reduced response times and reductions in cost. The algorithm

produced is different from other dispatch software available as it considers all factors relevant to the police dispatch problem. Using this method of resource allocation will help police with their aim to make UK counties operate as boundary-less areas.

Future work that could improve the algorithm further includes, expanding the weightings given to include other factors and use real time data to inform these weightings. Also future work could consider expanding the criteria in the selection process to include other response unit skills and experience. This would require a database of these skills being formed by the police force, a resource which is not currently available to dispatchers within current policing methods.

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