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# A PROMETHEE based uncertainty analysis of UK police force performance rank improvement

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**ABSTRACT**

The police forces in the UK are periodically compared with each other on their performance, by government and non-government bodies. This study demonstrates the employment of PROMETHEE in an investigation of the targeted performance rank improvement of individual UK police forces (with their 'most similar forces' groups). The graphical representations presented offer an insight into the implications of such a PROMETHEE based series of perceived improvement analyses. The goals of this study are twofold, firstly to exposit PROMETHEE based uncertainty analysis in rank improvement and secondly, how the subsequent results can form part of the evidence to aid in their performance strategies.

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## 1 Introduction

Crime statistics have been collected and published in the United Kingdom (UK) for over two hundred years. Since 1805 the UK Government's Home Office initially included court-based data about proceedings and convictions and from 1857, data about crimes reported to and recorded by the police were added. One of the main driving forces for such an initiative was an attempt by the British Parliament to exercise a level of control and monitoring of the predominately localised police forces of the time.

Such recording of crime statistics is not however unique to the United Kingdom. In 1929 the United States Department of Justice initiated a uniform crime report (UCR) programme and instructed the Federal Bureau of Investigation (FBI) to collect information on a selection of crimes reported to law enforcement agencies. Such crimes are comparable to those recorded in the UK and include homicide, rape, assault, burglary, motor vehicle theft, drug offences and criminal damage.

However it has long been recognised that there are inherent weaknesses in the collection and interpretation of such statistics particularly where they are used as a proxy measure for reviewing police performance. First, the level of recorded crime is subject to the uncontrollable variable of the public's attitude to reporting crime. Second, the police traditionally had discretion as to how and what they recorded as a crime and therefore some commentators have suggested that the police could distort the crime statistics in order to improve measured reported performance. Third, there has always been a difficulty in comparing the performance of local police forces and even more difficulty in aggregating such differences to form a coherent and realistic picture of police performance in a national context.

Given these difficulties attempts have been made in both the UK and US to develop other survey methods that remove such potential distortions and more accurately reflect the 'true' picture. First amongst these were attempts by American criminologists to develop large-scale population surveys to measure the extent of crime by recording the experiences of victims of crime. The first 'National Crime Victimization Survey' (NCVS) was conducted in the United States in 1973 and provided the first detailed picture of crime incidents, victims and trends. This successful innovation was subsequently followed in 1981 by the UK Government's own version, the British Crime Survey (BCS).

Thus, since the early eighties, the method of recording criminal activity has been the subject of significant investment in terms of research, from both academics and practitioners within and outside the criminal justice arena (CIPFA (2000); Ashby(2003); Fielding and Innes (2006). The consequence of which has resulted in a collection of 'criminal statistics' which provide an increasingly comprehensive account of patterns and trends of criminal activity. Within the UK (England and Wales) such data is collated by the Home Office and an official record of 'notifiable offences' recorded by the 43 police forces is reported by the Home Office in statistical bulletins. Such bulletins present a summary of the numbers of crimes captured by the British Crime Survey (BCS), and those crimes that are recorded by the police.

Given this context the use of crime statistics as a means of identifying levels and types of criminal activity within given geographic areas is a key element in considering measures to reduce criminal activity. Success in achieving this is regarded by the UK Government as one of the seven key performance indicators that have been used as a measure to assess overall police performance at Police Force level. Such assessments are intended to measure, compare and assess the performance of police forces in an effective, fair and transparent way. The assessments are intended to reflect the aim of focusing on the 'end results' delivered by police forces (with partners) so that, amongst others, police forces can manage and improve there own performance; police authorities can monitor local delivery and improvement; good practice can be identified and shared and problems can be addressed (Home Office, 2007)

Currently two assessments are made for each of the seven performance areas: Reducing Crime; Investigating Crime; Promoting Safety; Providing Assistance; Citizen Focus; Resource Use; and Local Policing. These assessments are derived from a combination of performance data and professional judgement. The first assessment concerns the performance delivered by a force over the last year. Typically, this judgement is made comparing the performance achieved by a force to that achieved by a group of most similar forces (MSF's). A second assessment is made on direction by comparing the performance of a force in one year to that achieved by the same force in the previous year.

Through the use of such assessments it is therefore possible to summarise an individual police force's performance across the Policing Performance Assessment Framework domains based upon the statutory performance indicators and Her Majesty's Inspectorate of Constabularies (HMIC's) baseline assessments. Such information can then be used to rank police forces in terms of their overall performance (within their MSF group).More specific information can then be utilised from the available performance data, to focus on one or more of the seven key performance areas, as a means of comparing a number of police forces within its MSF group. This paper will specifically concern itself with the areas relating to 'crime' and consider an important element of this, that being sanction detection levels for specific categories of crime.

Amongst the techniques utilised to investigate police performance there are data envelopment analysis and stochastic frontier analysis (Thanassoulis, 1995), which have used a range of measurements, input and output, to base their performance studies on. A related comment was outlined in the government sponsored Spottiswoode (2000) report identified the need for more efficiency based measurements. Conversely, the HMIC (2004) has adhered to the more output only driven performance measurement approaches. Drake and Simper (2005) succinctly describe the appropriateness of whether to employ input and output (efficiency) or just output (performance) criteria (see also Thanassoulis, 1995; Dadds and Scheide, 2000; Drake and Simper, 2003a, 2003b).

The difference in policing situations, including economic, social and geographical aspects, has motivated the UK government to define the use of 'most similar forces' (MSF) groups associated with each police force (Home Office, 2005).

This study looks at the ranking of individual police forces, with respect to their particular MSF group, based on a number of performance (output) criteria, namely certain sanction detection levels (clear up rates). The use of sanction detections is without loss of generality to the future use of other criteria (see, Drake and Simper, 2005; National Policing Plan 2004-2007). Sanction detections are easily interpretable to the public when comparative performance analyses are perceived, and are regularly reported in the national media (see, The Guardian, 2006).

The central technique utilised in this study is the PROMETHEE outranking method of multi-criteria decision making (Brans and Vincke, 1985, Brans *et al*., 1986). A PROMETHEE analysis operates on a number of criteria (here sanction detection levels), to establish a rank order of alternatives (here performance of police forces with their MSF groups). With its main application in the area of project ranking (Goletsis *et al*., 2003; Pohekar and Ramachandran, 2004; Simon *et al*., 2004), its relevance goes further including the performance of chemometric methods (Ni *et al*., 2004) and stock trading choices (Albadvi *et al*., 2006). At the technical level PROMETHEE has been employment/development in conjunction with other techniques, including the Analytic Hierarchy Process (Dağdeviren, 2008) and Multi-Objective Programming (Parreiras, and Vasconcelos, 2007).

Beyond the traditional PROMETHEE analysis, this study goes further with a series of concomitant uncertainty analyses presented (see Hyde *et al*., 2003; Hyde and Maier, 2006, Beynon and Wells, 2008). The motivation was the acknowledgement of uncertainties and subjectivities of criteria values and the overlooked impact of such variability to the identified rankings of alternatives. Each uncertainty analysis undertaken in this study allows the evaluation of the minimum changes in a considered police force's criteria values that would improve their rank position to that of a compared-to force (from within their MSF group). Defined as a constrained optimisation problem, this study utilises the novel trigonometric differential evolution method (Storn and Price, 1997; Fan and Lampinen, 2003), to effectively identify these described minimum changes.

Three UK police forces are specifically considered in this study, along with their respective MSF groups, the reported rankings and the concomitant uncertainty analyses are visually presented using a number of graphs. The graphs presented

take advantage of our natural ability to distinguish between patterns and observable characteristics (Chen, 2001), something relevant to the clear elucidation of information often purported by the government (Crime and Disorder Task Group, 2005, HMIC, 2005). Indeed, one reason for the utilization of PROMETHEE is that it offers a means of multi-criteria ranking analysis characterised by simplicity and clearness to the decision maker (Brans *et al*., 1986).

The rest of the paper is as follows: Section 2 briefly reflects upon the UK's government policy towards police forces performance measurement, including details of the utilised criteria and example police forces (with their MSF groups). In section 3, the PROMETHEE outranking method is provisionally applied to rank an identified police force with respect to its MSF group. In section 4, the issue of rank uncertainty is discussed, including the identification of the minimum changes a police force's criteria values to predicate the improvement to their rank position. In section 5, further PROMETHEE based uncertainty analyses are exposited on two other police forces and their respective MSF groups. In section 6, directions for future research are presented and conclusions reported.

## 2 Performance of the UK Police Service

In recent years there has been an increased focus on value for money and performance management within public services (Dadds and Scheide, 2000). In the UK, The Audit Commission, National Audit Office and Her Majesty's Inspectorate of Constabulary (HMIC) have been given a wider remit to examine police efficiency and effectiveness. Underpinning associated legislative changes has been the Government's emphasis on improving the performance of public services, and on the police service in particular (Barton, 2003). In part, this has stemmed from a desire both within the service and throughout the wider community for more transparency and accountability (HMIC, 2004). With the establishment of, 'a clear set of policing standards in order to drive up the performance of every police force and to reduce significantly the performance gap between the best and worst performing forces' (HMIC, 2004, p. 13).

The issue of performance measurement and target setting has been one of the central planks of the current government's reform agenda of the UK public

services. Such measurement has relied to a large extent upon data provided by the police on reported crime rates and crime clear-up rates (known as sanction detections - percentage of crimes for which someone is charged, summonsed, receives a caution or other formal sanction). Such levels have been maintained as critical indicators of performance and have historically constituted the main form of information for evaluating police services (Dadds and Scheide, 2000). Through their adoption, key performance indicators (KPIs), have been used to benchmark police forces against one another (Audit Commission, 1996; HMIC, 2004).

The issue of police performance and efficiency is understandably not restricted to the UK, Carrington *et al*. (1997) investigated the region of New South Wales (NSW) in Australia, identifying the pressure of the NSW Government to ensure that public service provision, including the police, was efficient and effective. Likewise, Dadds and Scheide (2000) conclude that whilst police performance measurement is important, there are limitations as to the interpretation of traditional police performance indicators as they are essentially social indicators. As a result it may be difficult to determine the exact nature and extent of the impact on police activity. Other examples of academic interest in the measurement of police performance includes Collier's (2006) account, highlighting the introduction of what police forces call 'activity-based' costing. This has been designed as a means of increasing the transparency of police operations, and is based on the assumption that the resources allocated to policing by government should be reflected in measurable performance improvement.

Returning to the UK national perspective, Drake and Simper (2003*a*) in a detailed discussion of police force efficiency analysis, with quantitative bias, identify that measuring police performance cannot be solely dependent on data provided by the police. Performance measurement is seen to be more robust if it is based on the outcomes (in terms of benefits to society) we are seeking to achieve, rather than the outputs recorded in relation to police activity (Home Office, 2005). Six indicators (considered herein as criteria) are utilised in this study to describe the performance of each police force, namely a sample of the sanction detection levels published in the Home Office Statistical Bulletin (Home Office, 2005), the list of which are; Violence against the person (Vap), Sexual offences (Sxo), Burglary (Bgy), Fraud and forgery (Faf), Criminal damage (Cdg) and Drug

offences (Dfc). These sanction detections have been used in similar studies, with evidence approving and not approving of their usage also published (see Thanassoulis, 1995; Drake and Simper, 2001, 2003*b*, 2005).

Historically, the ability to rank assess police forces (and other public organisations) has been through the presentation of national league tables. This is a favoured approach adopted by auditing bodies such as the Audit Commission, however such an approach has been critcised by some chief officers as too 'simplistic'. More recently the UK government has identified for each police force their 'most similar forces' (MSF) group, acknowledging that police forces operate in different environments and it is reasonable to expect that performance will vary as these environments differ in complexity (Home Office, 2005). Decisions on which forces are the most similar to each other are made using a range of geographic, demographic and socio-economic information (*ibid*.). Here, an example sub-group of three police forces is considered Cleveland, Merseyside and West Midlands, for which their respective MSF groups are presented in Figure 1.

The police forces included in the three MSF groups presented in Figure 1 (shaded regions), clearly demonstrate the subtle individualism of MSF groups (each group is unique but similar), including also the number of MSFs associated with a police force. For the three police forces considered, the collective MSF groups are made up of a total of seven police forces, namely Cleveland (Clvd), Greater Manchester (GMtr), Merseyside (Msyd), Northumbria (Ntmb), South Yorkshire (SYrk), West Midlands (WMdl) and West Yorkshire (WYrk). The details of these seven police forces are reported in Table 1.

**Table 1. Criteria details (sanction detections levels - %) of included police forces**

| Police Force | Vap | Sxo | Bgy | Faf | Cdg | Dfc |
|---|---|---|---|---|---|---|
| Cleveland | 50 | 46 | 13 | 37 | 12 | 94 |
| Greater Manchester | 54 | 30 | 18 | 9 | 15 | 33 |
| Merseyside | 68 | 40 | 16 | 15 | 12 | 93 |
| Northumbria | 57 | 33 | 12 | 50 | 14 | 98 |
| South Yorkshire | 59 | 36 | 16 | 35 | 13 | 89 |
| West Midlands | 46 | 29 | 10 | 18 | 11 | 91 |
| West Yorkshire | 51 | 31 | 15 | 28 | 12 | 93 |

In Table 1, brief inspection of the sanction detection levels across the different police forces highlights variations (discussed more specifically later).

## 3 PROMETHEE Analysis of a UK Police Force and its MSF Group

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is an outranking method of multi-criteria decision making (Brans and Vincke, 1985; Brans *et al*., 1986). Its introduction was to offer a means of MCDM analysis characterised by simplicity and clearness to the decision maker, when elucidating a rank order of considered alternatives towards some consequent (such as performance), based on a number of criteria (for a detailed description of the PROMETHEE techniques necessary for this study see Appendix A). In Brans *et al*. (1986), within their economic application, they stress how the incumbent parameters can be fixed by the decision maker. In this first expository application of PROMETHEE in police performance there is an emphasis on the automation of the whole process (see later).

For the police performance problem described in section 2, a single PROMETHEE analysis considers the comparative performance of a police force and its concomitant MSF group, based on levels of certain sanction detections (Vap, Sxo, Bgy, Faf, Cdg and Dfc). The police force first considered in this study is Cleveland, where six police forces make up Cleveland and its MSF group (see Figure 1*a*), the descriptive statistics of their levels of sanction detections are presented in Table 2 (using details in Table 1).

The results in Table 1 indicate the variation in levels of sanction detections across the six police forces. As mentioned earlier, it is accepted that no police forces are identical, even those in their MSF group (see section 2). It is interesting that some police forces perform better at detecting certain forms of crime than others. Particularly given that all police officers receive a similar form of training, independent of which constabulary they are employed by (Barton, 2003). While there may be pertinent efficiency issues different for the individual forces (Drake and Simper, 2005), here a PROMETHEE analysis is undertaken to performance rank the police forces, with respect to these publicly published details.

**Figure 1. Geographical representation of the MSF groups for the police forces, Cleveland, Merseyside and West Midlands.**


**Table 2. Descriptive statistic details of criteria (sanction detection levels - %) of Cleveland and its MSF group (see Figure 1a and Table 1)**

| Criteria | Vap | Sxo | Bgy | Faf | Cdg | Dfc |
|---|---|---|---|---|---|---|
| Min. | 46 | 29 | 10 | 15 | 11 | 89 |
| Max. | 68 | 46 | 16 | 50 | 14 | 98 |
| Mean | 55.1667 | 35.8333 | 13.6667 | 30.5000 | 12.3333 | 93.0000 |
| Std. Dev. | 7.1976 | 5.7566 | 2.2111 | 11.8708 | 0.9428 | 2.7688 |

The technical rudiments of the PROMETHEE method are presented in Appendix A. In summary criterion flow values ($\phi_i(\cdot)$) are found that quantify the preference of each police force over the others on a particular criterion, based on the differences between their criterion values, utilised in a Gaussian preference function (the standard deviation values reported in Table 2 are used to mitigate

the varying levels of dispersion inherent in the different criteria - $\sigma_k$ values in Appendix A). The criterion flow values for a police force are then aggregated to produce a net flow value ($\phi(\cdot)$), the set of which allow a ranking of the police forces considered to be directly established. The aggregation process includes the need for criteria importance weights to be identified prior to the actual analysis. Here, the six criteria were considered of equal importance ($w_i = 1/6$, $i = 1, \ldots, 6$).[1] The evaluated criterion and net flow values for each police force, Cleveland and its MSF group, are reported in Table 3.

The results in Table 3, have identified a rank ordering (bottom row) of the six police forces in the Cleveland MSF group, with Northumbria ($\phi$(Ntmb) = 1.5767) and West Midlands ($\phi$(WMdl) = –2.7814) found to be the top and bottom performance ranked, respectively, with Cleveland ($\phi$(Clvd) = 0.4465) fourth ranked in this group based on the six sanction detections criteria. These results are only pertinent to the Cleveland police force since the other police forces have their own unique MSF groups, which include different police forces and so would produce a different set of results.

**Table 3. Criterion and net flow values of the six police forces in Cleveland's MSF group, using PROMETHEE (police force abbreviations defined in section 2)**

| Force | Clvd | Msyd | Ntmb | SYrk | WMdl | WYrk |
|---|---|---|---|---|---|---|
| | | | | | | |
| $\phi_{\text{Vap}}(\cdot)$ | | | | | | |
| $\phi_{\text{Sxo}}(\cdot)$ | | | | | | |
| $\phi_{\text{Bgy}}(\cdot)$ | | | | | | |
| $\phi_{\text{Faf}}(\cdot)$ | | | | | | |
| $\phi_{\text{Cdg}}(\cdot)$ | | | | | | |
| $\phi_{\text{Dfc}}(\cdot)$ | –1.4689 | –1.9861 | 1.6654 | –0.4801 | –0.8946 | 0.0101 |
| | | | | | | |
| $\phi(\cdot)$ | 0.4465 | 0.7542 | 1.5767 | 0.5297 | –2.7814 | –0.5257 |
| Rank | 4 | 2 | 1 | 3 | 6 | 5 |

The criterion flow values presented in Table 3 elucidate the performance contribution of each criterion to the net flow value for a police force and its subsequent ranking (the larger a criterion value the more contribution). In the

[1] This is itself a generalisation; further research would incorporate different criteria importance weights, found using quantitative processes and/or expert opinion.

case of the Cleveland police force, the evidence from the criteria in decreasing order of contribution is Sexual offences ($\phi_{Sxo}$(Clvd) = 4.1167), Fraud and forgery (1.3030), Burglary (0.6325), Drug offences (−1.4689), Violence against the person (−1.7419) and Criminal damage (−2.8414). The dominant contribution of the Sexual offences criterion to the police force's fourth rank position is supported by referral to Tables 1 and 2, where with a 68% sanction detection level, Cleveland has the largest value of this criterion within its MSF group.

It is this rank order (or ones like it) that a particular police force would consider reacting to (Cleveland in this case), including how to improve their rank position, with respect to their MSF group. In the past this may have been whether to achieve a top performer status, or just to satisfy the public attention that will be brought on them by its publishing. The next section considers one such approach to this reaction, through the identification of the minimal changes in sanction detection levels that would improve a police force's rank position.

## 4 Performance Rank Uncertainty and Police Force Improvement

Within many applications using multi-criteria decision making techniques, there is an often ignored consideration to the sensitivity of an identified rank ordering (Fischer, 1995; Wolters and Mareschal, 1995). Hyde *et al*. (2003) and Hyde and Maier (2006) considered the changes to the criteria values of an alternative and the concomitant criteria importance weights, when using PROMETHEE, that would make their net flow value to be equivalent to that of a differently ranked alternative (see Appendix A for technical details). Here, within the police performance problem only changes to the criteria values associated with the considered police force are investigated (not the criteria importance weights).

The issue of changes of criteria values is to improve the rank position of a particular police force (based on sanction detection levels). From Table 3, with respect to its MSF group, Cleveland's fourth rank position would mean it could consider increasing (improving) its position to a higher rank. Moreover, they could attempt to attain any of the three higher rank positions above their original fourth rank position. Following Hyde *et al*. (2003) and Hyde and Maier (2006), the minimum changes necessary to its criteria values, to achieve each of the higher rank positions, are reported in Table 4.

**Table 4. Changes in criteria values of Cleveland police force to improve rank position**

| Criteria | Police force compared with Cleveland (Clvd) | | |
|---|---|---|---|
| | 3rd (SYrk) | 2nd (Msyd) | 1st (Ntmb) |
| Vap | 50.0206 (00.04%) | 50.0742 (00.15%) | 50.2653 (00.53%) |
| Sxo | 46.0000 (00.00%) | 46.0000 (00.00%) | 46.0000 (00.00%) |
| Bgy | 13.0736 (00.57%) | 13.2794 (02.15%) | 14.0132 (07.79%) |
| Faf | 37.0077 (00.02%) | 37.0188 (00.05%) | 37.1382 (00.37%) |
| Cdg | 12.1442 (01.20%) | 12.5316 (04.43%) | 13.6404 (13.67%) |
| Dfc | 94.0512 (00.05%) | 94.1772 (00.19%) | 94.7686 (00.82%) |
| | | | |
| $\phi$(Clvd) | 0.50988351 | 0.71379149 | 1.36838493 |
| $\phi(\cdot)$ | 0.50988351 | 0.71379148 | 1.36838493 |
| Distance | 0.17 (14.83) | 0.63 (29.22) | 2.09 (20.19) |

The results in Table 4 identify the proposed new criteria values of the Cleveland police force, which collectively, using PROMETHEE, would equate its final net flow value with that of the police force it is being compared with (each column). The bracketed values are the respective relative changes of the values from their original criteria values (see Appendix A). The net flow values of Cleveland ($\phi$(Clvd)) and the compared to police forces are given to eight decimal spaces in Table 4 to show they are almost equal values in each case. The $\phi$(Clvd) values are slightly larger due to the constraints described in Appendix A, conferring the considered police force takes the higher rank position from the compared to force.

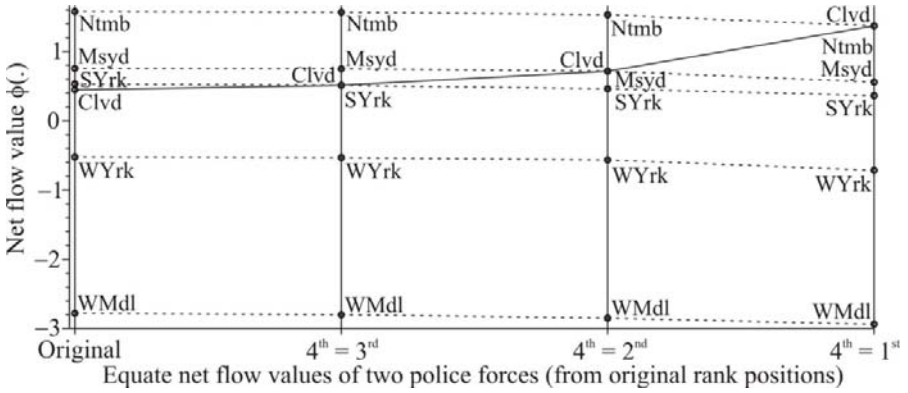
The bottom row of this table gives two Euclidean distance values for each analysis (see Appendix A). The first value is the distance of the proposed new criteria values of the Cleveland police force to the compared to force, the second (in brackets) is the distance of the original set of criteria values of the Cleveland police force to the compared to force. In each of the analyses, the first distance value is less than the second value, implying the proposed changes were less than what would have been necessary to be made to exactly match the criteria values of Cleveland to the compared to police force.

This highlights the subtlety of this analysis, namely these are the criteria values the Cleveland police force should strive towards to improve their performance rank position and not simply to match the compared to force's criteria values. This macro level analysis (all criteria changed at the same time) is advocated by the Home Office (2004), as discussed earlier (see section 2). Further, they can

contribute to the outline of a force's future development strategies, at least the basis for their reaction to improve their rank position. It is acknowledged, these results are only an aid to the intended strategy planning.

To further exposit the relationship between the considered Cleveland police force and the other forces, two graphical analyses are initially reported. The first considers the changes in the net flow values associated with all the police forces, subject to the changes of the criteria values of Cleveland (Table 4 includes a sample of these net flow values). Since the PROMETHEE analysis confers the sum of the net flow values over all the police forces equals zero (see Appendix B), all the net flow values of the police forces are changed in each analysis, to accommodate the change in $\phi$(Clvd), see Figure 2.

**Figure 2. Changes in net flow values of police forces when investigating the improvements in Cleveland's police force rank position.**

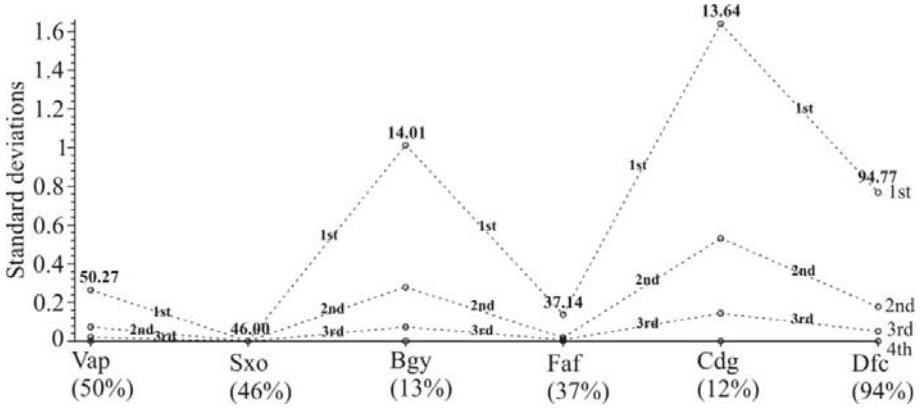



In Figure 2, along the *x*-axis is the rank position of the police force the fourth placed Cleveland police force was compared to (to produce equal net flow values), the *y*-axis shows the net flow value scale, each circle in the graph represents a net flow value. Furthest left are the original net flow values using the original criteria values of Cleveland (as presented in the penultimate row in Table 3). The vertical lines report the changes in net flow values of the six police forces when comparing Cleveland with the successive higher ranked police forces. What is first noticeable is the distance of the bottom two ranked police forces from the other police forces based on their net flow values (see Table 3).

With the Cleveland police force ranked fourth, its three improvements up the rank order are clearly shown (the solid line in Figure 2). A small movement is

necessary to achieve the third rank position, slightly more change is then evident to achieve second place, with a noticeably larger change necessary when achieving the top rank position (left to right across the graph). There is a near uniform decrease in the net flow values associated with the other police forces to accommodate the concomitant increase of $\phi$(Clvd), a consequence of the sum of the net flow values equals zero. The next consideration is on the progressive changes required in the criteria values of the Cleveland police force to achieve each improved rank position, see Figure 3.

**Figure 3. Progressive changes of the criteria values of the Cleveland police force.**




In Figure 3, the *x*-axis lists the six criteria (sanction detections) used to model the performance of the six police forces in the Cleveland MSF group (using PROMETHEE), also shown are the original sanction detection levels of the Cleveland police force (along the bottom axis). The *y*-axis identifies the level of change in a particular detection rate, from its original value (based on the number of standard deviations away from the original value). The series of vertical points connected by dashed lines are the successive changes of the respective criteria values, to improve to a particular rank position (given in Table 4).

To illustrate, for the Vap criterion its base (original) detection level value is 50% and to move up the rank order of police forces this value is required to increase successively to 50.0206%, 50.0742% and 50.2653%. The most noticeable relative change is associated with the criminal damage criterion (Cdg), it is required to successively increase from 12% to 12.1442%, 12.5316% and 13.6404%,

respectively. It is again noted, all changes of the detection rates need to be made to achieve the desired improved rank position.

## 5 Rank Improvement Analyses of Merseyside and West Midlands Police Forces

This section undertakes further PROMETHEE based analyses on two other police forces, namely Merseyside and West Midlands. Due to the non-symmetric relationship of memberships of MSF groups for police forces, consideration of another police force means a completely new PROMETHEE analysis, etc. That is, if a member of the MSF group of the Cleveland police force is to be considered, none of the results presented in the previous sections can be utilised, instead this police force has to be investigated with respect to its own concomitant MSF group.

Contrary to the previous detailed elucidation of the possible performance improvement of the Cleveland police force, here brief analyses are given on the two police forces. The two police forces next considered are Merseyside and West Midlands, and as will be shown, the associated results are at the extremes of what can be considered in terms of a police force's rank improvement.

### Merseyside Police Force

The Merseyside police force was present in the MSF group of Cleveland discussed previously. When it is the considered police force the member police forces of its MSF group were shown in Figure 1*b* (six police forces in total). The descriptive statistics of their levels of sanction detections are presented in Table 5 (using the details in Table 1).

**Table 5. Descriptive statistic details of criteria (sanction detection levels - %) of Merseyside and its MSF group (see Figure 1b and Table 1)**

| Criteria | Vap | Sxo | Bgy | Faf | Cdg | Dfc |
|---|---|---|---|---|---|---|
| Min | 46 | 29 | 9 | 15 | 11 | 91 |
| Max | 68 | 46 | 16 | 50 | 14 | 98 |
| Mean | 54.3333 | 34.8333 | 12.5000 | 30.1667 | 12.1667 | 93.6667 |
| Std. Dev. | 6.9921 | 6.1486 | 2.5000 | 11.7674 | 0.8975 | 2.1344 |

The results in Table 5, as in Table 2 when referring to the Cleveland police force, indicate the variation in levels of sanction detections across the six police forces. The associated PROMETHEE analysis on the Merseyside police force and its MSF group is briefly reported in Table 6.

**Table 6. Net flow values and final ranking of the six police forces in the Merseyside MSF group, using PROMETHEE**

| Force | Clvd | GMtr | Msyd | Ntmb | WMdl | WYrk |
|---|---|---|---|---|---|---|
| $\phi(\cdot)$ | 0.7312 | –0.9654 | 0.9788 | 2.0725 | –2.5293 | –0.2878 |
| Rank | 3 | 5 | 2 | 1 | 6 | 4 |

In Table 6, for brevity, only the associated net flow values are presented, which enable the rank order of the considered police forces to be identified. The results show the Merseyside police force to be second ranked, behind the first ranked Northumberland police force. There are levels of similarity in these ranking results to those for the Cleveland police force, due to the similarities in the member police forces of the concomitant MSF groups. Since only the rank improvement of Merseyside can be considered (due to the non-symmetric relationship of the MSF groups employed), its second rank position means that its improvement to just the first rank position is possible. Again, using the uncertainty analysis aspect with PROMETHEE, the minimum changes to the criteria (sanction detection levels) of the Merseyside police force can be found that change its net flow value to be just above that of the first ranked police force (Northumberland in this case), see Figures 4 and 5.

**Figure 4. Changes in net flow values of police forces when investigating the improvements in Merseyside's police force rank position.**

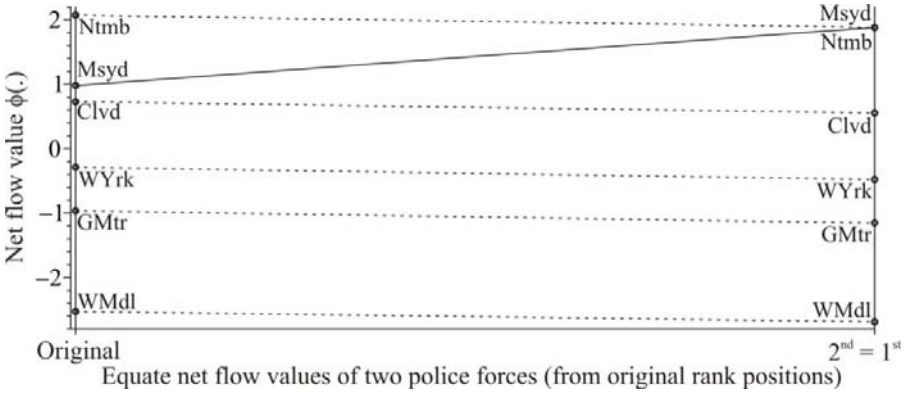
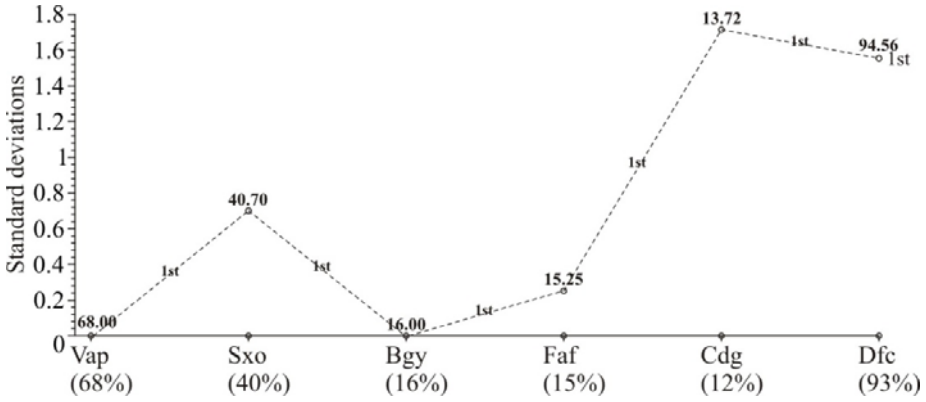


**Figure 5. Progressive changes of the criteria values of the Cleveland police force.**




In Figure 4, based on the sanction detection levels, the changes to the original Merseyside values are with respect to Criminal damage, Sexual offences and Violence against the person. The Faf criterion is interesting here since from the above diagram it can be seen that the first and second police forces have the largest and smallest of this sanction detection amongst all six police forces considered. Moreover, there is no identified change prescribed to this criterion.

**West Midlands Police Force**

The West Midlands police force was present in the MSF groups of Cleveland and Merseyside discussed previously. When it is the considered police force, the member police forces of its MSF group were shown in Figure 1*c* (seven police forces in total), Table 7 shows certain descriptive statistics on the sanction detections.

**Table 7. Descriptive statistic details of criteria (sanction detection levels - %) of West Midlands and its MSF group (see Figure 1c and Table 1)**

| Criteria | Vap | Sxo | Bgy | Faf | Cdg | Dfc |
|---|---|---|---|---|---|---|
| Min | 46 | 29 | 9 | 15 | 11 | 89 |
| Max | 68 | 46 | 16 | 50 | 14 | 98 |
| Mean | 55.0000 | 35.0000 | 13.0000 | 30.8571 | 12.2857 | 93.0000 |
| Std. Dev. | 6.6762 | 5.7071 | 2.6186 | 11.0250 | 0.8806 | 2.5635 |

With the variations in the levels of sanction detections of the West Midlands police force and those in its MSF group evident in Table 7, a PROMETHEE

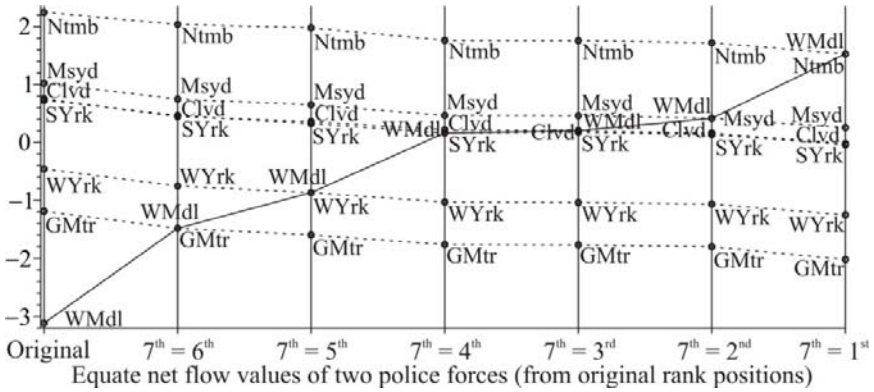
analysis is undertaken on the group of police forces to achieve a perceived rank order of their performance, see Table 8.

**Table 8. Net flow values and final ranking of the seven police forces in the West Midlands MSF group, using PROMETHEE**

| Force | Clvd | GMtr | Msyd | Ntmb | SYrk | WMdl | WYrk |
|---|---|---|---|---|---|---|---|
| $\phi(\cdot)$ | 0.7548 | –1.1844 | 1.0235 | 2.2462 | 0.7328 | –3.1162 | –0.4567 |
| Rank | 3 | 6 | 2 | 1 | 4 | 7 | 5 |

The net flow values reported in Table 8, discern the PROMETHEE based performance ranking of the West Midlands police force and its concomitant MSF group. The results show the West Midlands to be the bottom (seventh) ranked police force here. With respect to the West Midlands police and its possible improvement in rank position, there are six different options, namely their improvement to any of the six rank positions above them. For each improving rank position, a PROMETHEE uncertainty analysis can be undertaken, in each case finding the minimum changes in their criteria to achieve the individual rank improvements (see Appendix A), see Figures 6 and 7.

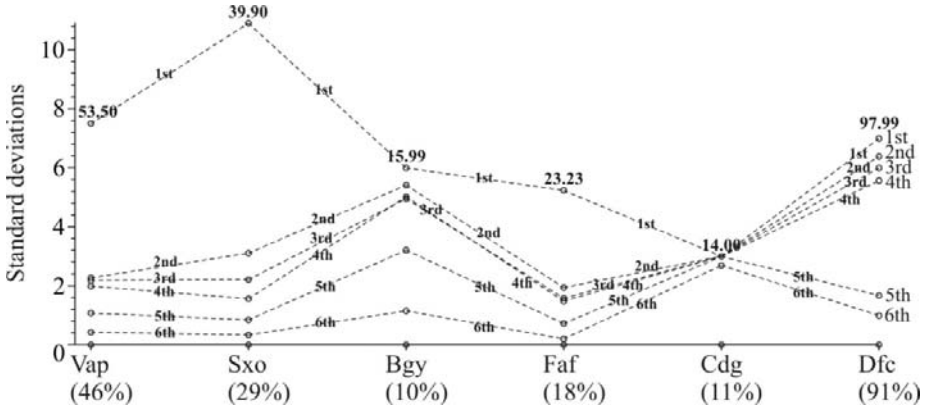
**Figure 6. Changes in net flow values of police forces when investigating the improvements in West Midlands' police force rank position.**




In Figure 6, the progressive changes in the net flow value associated with the West Midlands (WMdl) police force are shown, and other police forces, that moves it up the performance ranking, with respect to its MSF group. In Figure 7, the specific changes of the individual criteria are shown that conferred the rank improvement of the West Midlands police force (net flow value in Figure 6).

Moreover, working though the necessary changes to achieve sixth to first rank positions, there is not a consistent change across the criteria.

**Figure 7. Progressive changes of the criteria values of the Cleveland police force.**




The results in this section, concerning the two police forces, Merseyside and West Midlands, and their respective MSF groups, are at the different extremes of the results that could be presented on a single police force. Moreover, the occasions when the considered police force is second or last ranked with respect to itself and concomitant MSF group.

## 6 Conclusions and Future Research

Within the public sector there is prevalence for comparative analysis of organisations through their ranking, previously this was predominantly presented in the form of league tables. Successive governments (UK) have had to balance the publics' legislative right for published rankings and the protection of those organisations being ranked against inappropriate findings. The UK police service is a prime example of this 'delicate path' approach to the comparative analysis of the constituent police forces. An example, pertinent to this study, is the recent establishment of 'most similar forces' (MSF) groups for each police force, which due to their non-symmetric nature of membership mitigates the possibility for significant large scale comparative performance analysis of UK police forces.

The technique employed in this study is PROMETHEE, known for being a multi-criteria decision making technique whose approach is based on simplicity and clearness. Its development here is in the previously introduced uncertainty analysis adapted to aid in the elucidation of rank improvement of police forces (in

this case). The subsequent analysis operates within the confines of the MSF group system incumbencies. The resultant performance analyses presented, using PROMETHEE, each concern an individual police force and their concomitant MSF group. The criteria used to formulate the ranking of the police forces were publicly available sanction detections levels, this was without loss of generality, and future research should investigate how the analysis approach outlined here can look into more efficiency based rankings of police forces.

The identified rankings of the police forces based on their levels of sanction detections, are considered to only tell part of the story. Moreover, this study has considered the sensitivity of the rank orders found, here what minimum changes to a police force's criteria value are necessary to improve their rank to a particular position. Perhaps most importantly, the findings show that analysis techniques can be used to produce results that can aid in strategy planning (offering quantitative evidence of course), whether more pertinent techniques exists is not the question (such as data envelopment analysis), if they do then can they be likewise developed to investigate rank improvement, in the way the PROMETHEE analyses have done.

**Appendix A: The PROMETHREE Technique and Uncertainty Analysis**

PROMETHEE quantifies a ranking of alternatives through the pairwise comparison between their criterion values (Brans *et al.*, 1986). To express the preference structure of alternatives and to withdraw the scaling effects of the $K$ criteria generalised criterion preference functions $P_k(\cdot, \cdot)$ ($k = 1, \ldots, K$) are defined. Each $P_k(a_i, a_j) \in [0, 1]$ confers the directed intensity of preference of alternative $a_i$ over $a_j$, with respect to a criterion $c_k$, interpreted in the limits as (*ibid.*):

$$P_k(a_i, a_j) = 0 \Leftrightarrow a_i \text{ is not better than } a_j \text{ with respect to criterion } c_k$$

$$P_k(a_i, a_j) = 1 \Leftrightarrow a_i \text{ is 'strictly' better than } a_j \text{ with respect to criterion } c_k$$

It follows, A *criterion flow* $\phi_k(a_i)$ for an alternative $a_i$ from a criterion $c_k$ is defined by:

$$\phi_k(a_i) = \sum_{a_j \in A} \{P_k(a_i, a_j) - P_k(a_j, a_i)\},$$

where $A$ is the set of $N$ alternatives considered, it follows $-(N-1) \le \phi_k(a_i) \le N-1$ and $\sum_{a_i \in A} \phi_k(a_i) = 0$. A criterion flow represents the preference of an alternative over the other $(N-1)$ alternatives, over a criterion. A *net flow* $\phi(a_i)$ value is then defined by:

$$\boldsymbol{\phi(a_i)} = \sum_{k=1}^{K} w_k \phi_k(a_i),$$

where $w_k$, $k = 1, \ldots, K$ are the relative criteria importance weights. The net flow values exposit the relevant rank order of the $N$ alternatives. From Brans *et al*. (1986), here the Gaussian form of $P_k(a_i, a_j)$ is adopted, given by:

$$P_k(a_i, a_j) = \begin{cases} 1 - \exp\{-d^2 / 2\sigma_k^2\} & \text{if } a_i > a_j \\ 0 & \text{if } a_i < a_j \end{cases}$$

where $d = v_{a_i,k} - v_{a_j,k}$ is the difference between criteria values and $\sigma_k$ a level of dispersion of the criteria values, standard deviation ($\sigma_k$) of a set of criteria values. The sensitivity analysis of Hyde *et al*. (2003) employed here considers the change to the $r_1^{\text{th}}$ ranked alternative's criteria values so its net flow value is larger than or equal to that of the $r_2^{\text{th}}$ ranked, $\phi(a_{r_1}) \ge \phi(a_{r_2})$. A Euclidean based measure ($d_{r_1,r_2}$) allows the minimum changes necessary over all the criteria values (at once) that improves an alternative's rank position, given by:

$$d_{r_1,r_2} = \sqrt{\sum_{k=1}^{K} \left(w_k^i - w_k^o\right)^2 + \left(v_{r_1,k}^i - v_{r_1,k}^o\right)^2},$$

where $w_k^i$ and $w_k^o$ are the initial and optimised criteria importance weights subject to $\sum_{k=1}^{K} w_k^i = \sum_{k=1}^{K} w_k^o$ and $v_{r_1,k}^i$ and $v_{r_1,k}^o$ are the initial and optimised (standardised) criteria values. Further constraints on the criteria values of the $r_1^{\text{th}}$ ranked alternative are that they are kept within known domains, given by $\text{LL}_{v,k} \le v_{r_1,k}^o \le \text{UL}_{v,k}$ $k = 1, \ldots, K$, where were, these bounds $\text{LL}_{v,k}$ and $\text{UL}_{v,k}$ are the minimum and

maximum values, respectively, of each criterion (similar for criteria weights). Defined as a constrained optimisation problem, it is solved here using the evolutionary algorithm, trigonometric differential evolution (Storn and Price, 1997; Fan and Lampinen, 2003), with objective function $d_{r_1,r_2}$. The measure of the relative (percentage) change of the individual criterion values $\Delta^{v_{r_1,k}}$, is given by:

$$\Delta v_{r_1,k} = \frac{v^o_{r_1,k} - v^i_{r_1,k}}{v^i_{r_1,k}} \times 100\%.$$

Hyde et al. (2003) suggest that this measure allows the identification of the most critical parameters (criteria values) in the uncertainty analysis.

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