Mobile Access to Information Systems in law Enforcement: An Evaluation of its Implications for Data Quality

Rachael Lindsay, Thomas Jackson and Louise Cooke
Loughborough University, UK
r.e.lindsay@lboro.ac.uk
t.w.jackson.@lboro.ac.uk
l.cooke@lboro.ac.uk

Abstract: A recent UK government initiative enables police officers to input information directly into policing information systems via mobile devices. However, the impact and implications on data quality have not been assessed. The events of 9/11 and the Soham murders in the UK in 2002 may reflect high profile incidents of failure in information management practice within police forces that have amplified the need to scrutinise the monitoring of data quality. The tragedy of the Soham murders was partly caused by poor quality information regarding the offender, Ian Huntley, being held on disparate information systems. Consequently, intelligence and information held on people must be fully accurate, and therefore data quality plays a pivotal role. Despite the apparent severe impact of poor data quality on organisational effectiveness and decision-making, previous research appears to have addressed these issues only within non-policing sectors. The paper investigates what measures are used to monitor data quality via an empirical study within a UK police force, the Leicestershire Constabulary. It also evaluates the design of the interface of the crime-input form and the impact this has on inputting quality information into the crime recording system, along with the implications of this for modern-day law enforcement. Measurement of data quality was investigated by mapping aspects of the data quality monitoring process identified via qualitative data from semi-structured interviews against the key attributes of data quality derived from a literature review. The design of the crime-recording interface was evaluated via a series of focus groups with operational users of mobile technology prior to and following implementation of mobile devices. The research found that there are some processes in place to check that data follows specific standards, such as the recording of dates of birth. However, these processes only take into consideration the structural completeness of data, and other measurements of data quality, such as accuracy, timeliness, relevance, understandability and consistency are not considered. It also found that the existing interface is inefficient for a mobile environment, as there are numerous free-text fields and duplication of data entry caused by a lack of system integration. The paper contributes to the existing small body of knowledge on data quality within a mobile policing environment. This knowledge can be applied by other law enforcement organisations looking to provide mobile access to their information and knowledge environment without reducing the level of data quality as a result of direct input of information.

Keywords: mobile working, law enforcement, evaluation, data quality, interface design

1. Introduction

In order for police officers to exploit information provided by technology and correlate this information to trace suspects, it is argued that better quality data is fundamental so that all information gathered can be applied and reused to new situations (Informatica, 2008). This is emphasised by Baumber (2007), who suggests that a key concern for police forces is the quality of information stored in their IT systems, as within 43 individual police forces there are 270 different IT systems in operation. It is suggested that disclosure of inaccurate information may place a person at personal risk, and a common issue is that information retrieved is inadequately recorded or verified (*Ibid.*). For example, the child murder in the UK village of Soham in 2003 was partly caused by poor quality information regarding the offender, Ian Huntley, being held on disparate information systems (Orna, 2005). Eleven separate allegations of criminal offences were made against Huntley between 1995 and 1999, prior to his appointment as the Caretaker at the Soham Village College in November 2001. In direct response to this tragedy, the code of practice known as the Management of Police Information (MoPI) was implemented into UK police forces in 2005 to ensure that intelligence and information held on people is fully accurate (NPIA, 2007), and therefore data quality plays a pivotal role.

Following a significant investment by the UK Government, UK police forces are currently adding a mobile component to their information processes. The mobile data terminal (MDT) solution within the Leicestershire Constabulary enables officers to enter and access information into the complex range of information systems whilst on the move. This changes the previous process for inputting crime details, whereby details were faxed to the crime bureau and input by a member of the crime bureau. The MDT can be removed from its in-vehicle docking station and can be used out of the vehicle (such

as in properties) as a portable device, allowing "anytime anywhere" crime recording. However, allowing officers direct access to information via mobile technology may have implications for data quality, but it appears little is yet known what these implications are. Baumber (2007) concurs that the introduction of technology to increase access to information may also lead to information quality becoming a priority for the police service. It is therefore important to understand the impact that providing mobile access to information will have on the data quality of police information systems. The development of an information system known as the Police National Database (PND), scheduled for delivery in 2010, will allow all UK police forces to access information across the country rather than on a local level. The PND may place additional pressure and serve as a key driver for ensuring good quality data, so that information input from a local source (such as from a mobile device) will be correct in order to use as a basis for decision-making on a national scale.

This paper reports on what measures are used to monitor data quality via an empirical study within a UK police force, the Leicestershire Constabulary. It also seeks to investigate the user interface and the impact this has on inputting quality information into the crime recording system within a mobile context.

2. Measuring data quality

Data quality has emerged as a major issue due to its potential severe impact on organisational effectiveness (Umar *et al,* 1999; Even & Shankaranarayanan, 2009; Batini *et al,* 2009). There are many different views and definitions of data quality, but a generally accepted definition within the literature is 'a product, service, or datum X is of higher quality than product, service or datum Y if X meets customer needs better than Y' (Ibid.). In other words, data quality involves meeting the needs of knowledge workers and customers. Within the literature, there are many attributes that contribute towards data quality. An analysis of the literature conducted by the author within Table 1 reveals that the most common attributes of data quality are accuracy, completeness, timeliness, relevance, understandability, accessibility and consistency.

The accuracy dimension can be defined as the correctness of data with respect to real life. Completeness relates to the degree to which values are present in data collection and sufficient (Parker *et al,* 2006). The attribute of timeliness measures whether the information is available in the required timeframe of the user (Forslund, 2007), whilst the level of relevance indicates whether the information addresses the users needs, and the attribute understandability refers to how easy it is to comprehend the information (Al-Hakim, 2007). The level of accessibility determines the degree to which information can be retrieved when required, and consistency ensures that two or more data items do not conflict with each other (*Ibid)*. Cellco (1995) argues that dirty data is causing major problems with data warehouses; therefore many users are retrieving wrong information from their data warehouses. Similarly, Redman (1998) suggests that the impact of poor data quality include 'customer dissatisfaction, increased operational cost, less effective decision-making, and a reduced ability to make and execute strategy'. The most important point here may relate to the ability to make decisions, as echoed in a report by Mayberry (2002) who suggests that 'data quality problems cost U.S. businesses more than $600 billion per year' and an 'inability to make sound decisions based on accurate information'.

Previous research has recognised the importance of data quality within a variety of sectors. For example, Umar *et al* (1999) identified lessons learned from a large-scale case study conducted in the telecommunications industry. The study found the key issues affecting data quality included inconsistency among systems, for example the same information does not exist in all required systems, poor system architecture causing silos of information, lack of standardisation for data entry and a lack of data and information standards. Similarly, the issues of multiple sources of data were apparent within a study of enterprise resource planning system implementation by Xu *et al* (2002)*,* along with misrepresentation of information due to different interfaces between systems. Gendron & D'Onofrio (2001) found that data quality was of particular importance within the healthcare industry and the key attributes of data quality discussed previously were felt by healthcare managers to be of relevance to conducting operational activities successfully.

These messages learned from previous studies are relevant for modern police forces, as illustrated by the introduction of MoPI discussed in section 1. Despite this, it appears that little research has been done before in this area, yet recommendations are needed to manage data quality levels within a mobile information environment, in order to allow the Constabulary to align with the MoPI code of

practice (NPIA, 2007). In line with the review of the data quality literature, MoPI states that police information should be accurate, adequate, relevant and timely (*Ibid.*). This is supported by a report by the Audit Commission (2007), which states that 'police forces need to sustain and embed high standards of data quality through effective procedures and systems'. Their findings showed that the data quality of Leicestershire had improved in 2006/07 to a grading of excellent from a grading of fair in 2005/06. However, little evidence seems to be available to indicate the perceptions of data quality following the creation of a mobile component to policing processes.

Table 1: Evaluation of data quality attributes

Data quality literature	Accuracy	Accessibility	Appropriate amount	Believability	Completeness	Concise representation	Concurrency of redundant or distributed data	Consistency	Contextual clarity	Currency	Definition conformance	Ease of operation	Interpretability	Integrity	Non-duplication	Objectivity	Precision	Relevance	Reliability	Rightness or fact completeness	Security	Structure	Timeliness	Understandability	Usability	Validity
Umar et al (1999)	x				x			x		x																
Wang & Strong (1996)	x				x			x		x																
Ballou & Pazer (1985)	x				x			x		x																
Cappiello (2005)	x				x			x		x																
English (2005)	x	x			x		x		x		x					x		x			x		x		x	x
Lee et al (2004)	x		x	x	x	x		x				x	x			x		x	x		x		x	x		
Parker et al (2006)	x	x	x	x	x											x		x		x			x			
Forslund (2007)	x	x																	x				x			
Miller (1996)	x	x			x	x												x			x		x	x		x
Shankaranarayanan & Cai (2006)	x				x																		x			
Li & Lin (2006)	x		x					x															x	x		
Miller (2005)	x	x		x	x										x	x	x	x					x	x		
McLeod & Hare (2007)									x					x				x					x			x
Al-Hakim (2007)	x	x	x	x	x	x		x				x	x			x		x			x		x	x		
Smith (2007)		x											x					x					x			
Sheperd & Yeo (2003)	x				x																x			x	x	
Redman (2001)	x				x					x			x													
Huang et al (1999)	x				x																			x		
Eppler (2003)		x				x													x							
Lee et al (2006)	x	x	x	x	x			x															x			
Olson (2003)	x				x														x				x	x		x
FREQUENCY	18	8	5	5	16	4	1	8	2	5	1	2	4	1	1	4	2	8	4	2	4	1	11	9	3	3

3. Research design

Participants within the Leicestershire Constabulary were selected for interviews and focus groups, based on purposive sampling. Table two summarises the methods used for the research.

Table 2: The research domain

Phase of research	Method	Sample & size
Identification of measures used to monitor data quality within the Constabulary	1 x semi-structured interview Results mapped against literature	1 x Constabulary personnel responsible for overseeing the implementation of MoPI (referred to as the 'MoPI manager' throughout the paper)
Ease of inputting information into information systems	15 x focus groups	78 operational police officers

Measurement of data quality was investigated by mapping aspects of the data quality monitoring process identified via qualitative data from semi-structured interviews against the key attributes of data quality derived from the literature review (as shown in section 1). Focus groups were used to explore the perceived ease of inputting information into mobile information systems. The authors intended to conduct a series of observational 'work-shadowing' exercises to explore this issue in a more objective manner. However, a large number of officers that are using mobile technology in police vehicles are single-crewed, meaning it is difficult to input information whilst driving and completing operational duties. Therefore, the use of observation was trialled but only a small amount of data could be collected. The method was later rejected for the research. Qualitative methods were largely used to explore the issues in-depth; where as quantitative methods such as a questionnaire may lack this in-depth understanding. The one interview deployed for phase one of the research offers may be viewed as a limitation in terms of assessing the data quality process. However, this one person was specifically sampled because they have overall responsibility for overseeing the management of police information ('MoPI') and thus have a good understanding of the key aspects of the data quality monitoring process. A face-to-face semi structured interviews was conducted with the MoPI manager to gain 'expert opinion' on the key features of measuring data quality within the Constabulary. An expert is someone with knowledge and practical engagement with the issues under investigation (Adler & Ziglio, 1996: 14). In this sense, a manager overseeing the implementation of a policy closely related to data quality seemed most appropriate.

4. Results

4.1 Data quality monitoring process

The interview with the MoPI manager highlighted the importance of data quality, for example for one person their details are held within 32 different systems. If each of the 32 records has varying field entries, it can make it difficult to uniquely identify the 32 records as the same person, which can lead to poor decisions being made. For example, if the address of person X is recorded as 19 Arcadia Avenue within one system, but is recorded as 91 Arcadia Avenue within another system, an officer may choose to break and enter the wrong address, which may reduce the level of public confidence within the police service. Therefore monitoring the quality of data within systems may reduce such misjudgements.

It was found that the main data quality-monitoring process that is followed within the Constabulary on a monthly basis only monitors the accuracy of a small amount of data – the names and dates of birth (DOB) fields of records held within the main systems (CIS, custody system, child abuse system and firearms system). However, these fields are the main fields that are used when searching for people within systems so it is important that they are checked for accuracy. The fields are checked for accuracy and placed into three categories – 'good', 'sparse' and 'bad', and statistics are produced on the levels of data within each category. 'Good' data includes name & DOB fields that are completed correctly; 'sparse' data means that names & DOB fields of systems lack some data, such as first name; and 'bad' data means that name & DOB fields of system are completed incorrectly, such as '1853' entered as a year.

It was revealed that the Constabulary used to have the greatest number of 'bad' data than the other police forces within the East Midlands region, but since this monitoring process was introduced the MoPI manager suggested that the level of 'bad' data has been dramatically reduced. The evidence also identified particular points in time where the level of 'bad' data has increased. For example, between the 8th May 2007 and 12th June 2007 the level of 'good' data dropped from 96.16 per cent to 93.30 per cent. This was due to a change in the crime recording process. All domestic abuse reports are recorded on the CIS, however as there are often counter-allegations then all parties are usually registered as joint aggrieved, which does not require entry of dates of birth. However, the CIS

has a mandatory field for the date of birth, which leaves officers recording dates of birth as 01/01/1900. Prior to the 12th June 2007, this data was filtered from the data quality monitoring process – hence a drop in the number of good data submissions. This decision was made to ensure that persons involved locally in domestic abuse allegations were circulated nationally, even with known fictitious dates of birth. Similarly, between the 8th April 2008 and 13th May 2008, the level of 'good' data increased from 93.03 per cent to 94.03 per cent. During the interview it was found that this was related to the ongoing data quality monitoring process, whereby 'bad' data is returned monthly to the business areas for the CIS with a request to investigate and amend accordingly. It was suggested this could also be due to the initial introduction of MDTs. The level of 'good' data further increased from 94.93 per cent to 95 per cent between 9th September 2008 and 14th October 2008, which was suggested in the interview to be related to the full rollout of mobile technology. This may suggest that mobile technology is having a positive impact on certain elements of data quality, since information is captured whilst at the scene thereby increasing the level of accuracy.

Whilst the MoPI manager suggested that this data quality-monitoring process has proven to be quite effective, he also implied that it is more of a reactive process and does not detect issues at source, therefore when data is inputted. He explained how a feature has been developed just for the Constabulary to assist users in entering information into the CIS. The feature is an icon that looks like a 'fox' and works in a similar way to the 'paperclip' wizard that appears within Microsoft applications. The icon appears when a user is entering data into the 'name' and 'date of birth' fields and validates the data if they appear to enter something that appears not to make sense, for example, entering the year '1858' instead of '1958'. The Constabulary have decided to not make the 'fox' icon available for all fields, as users could become frustrated and close the icon every time it appears, which would reduce its effectiveness. The icon detects data quality issues at source and as a result, the MoPI manager suggested that it has helped to improve the level of data quality within the CIS. The feature aligns with the key lessons learned from a study into data quality issues within the telecommunications industry, where a uniform valid point of entry is recommended (Umar *et al,* 1999). Within a mobile information environment, such a feature is especially important as officers can now directly input information into information systems, so it is better to detect issues at an early stage. During focus groups, police officers suggested that replicating the existing systems within a mobile environment would be unsatisfactory. Therefore the implementation of this feature may support the preferences of police officers, which are discussed further within section 3

4.2 Assessing the design of the crime input-form interface

Prior to the introduction of mobile technology, focus group participants expressed the need for the CIS interface to be simple and easy to use, as the emphasis will be on the officer to input information. This is illustrated by the following examples:

> *"The interface must be different – it is no good just replicating the old CIS on MDTs"*

> *"There is a need for entering checks to be in place. There are current frustrations over the lack of content of information"*

These findings were mirrored by officers following the rollout of MDTs, again suggesting the need for prompts to avoid missing important information and removal of duplicating information such as the address of the victim: -

> *"When inputting crimes we have to input duplicate information e.g. the aggrieved address. Prompts are necessary so that we do not miss important information"*

> *"Drop-down categories should be introduced to fields such as 'property' to improve on searchable fields and data quality"*

Within the wider-evaluation focus groups, a group of officers were asked on a scale of one to five (with one being easy and five being difficult) how they would rate the input of information into the CIS, and rated this as 3.5. This indicates that the input of information is more difficult than the paper-based crime recording process. They suggested that this was due to a number of reasons. Firstly, the CIS input screens do not follow a logical order, meaning that officers sometimes forget important information within a later screen. Secondly, they stated that the CIS has some mandatory fields that must be completed before the system allows data to be saved, but mandatory fields can be overridden by entry of inaccurate data. Thirdly, they asserted that the gazetteer within the CIS used to look up addresses contains many errors and requires a high degree of accuracy to look up and enter the correct location: -

> *"The ability of the Gazetteer to locate an address despite poor spelling or inaccurate information needs improving"*

This issue means that locations often have to be entered as free text, which may reduce the level of data quality. The final issue was that they suggested free text fields allowed inaccuracy of data, for example when inputting details of stolen properties it can be difficult to know what information to enter.

Another issue raised within the post-trial focus groups was the lack of integration of systems. For example, the incident management system is not linked to the CIS so both systems have to be updated in order to provide full details of a crime. Before mobile technology, crime related information was input and shared by the call management centre to officers via the radio. Officers in the post-trial focus groups were concerned about the expectation to input into the various information systems whilst at the same time completing their operational duties. These issues carry particular relevance for data quality: entry of data into large number of free-text fields and several systems whilst a police officer is working within a time-critical operational environment may negatively affect the accuracy, completeness, timeliness, accessibility and consistency of data held within police systems (Table 3). This impact is likely to be magnified during the entry of data via a mobile device (Table 3), unless changes are made to suit data entry within a mobile information environment. The design of the CIS interface and integration of a complex range of data entry interfaces remain open questions in order to maintain quality information whilst allowing information systems to be updated remotely.

Table 3: Screen design issues versus data quality problems

Screen design issue	General screen design issue	MDT specific screen design issue	Accuracy	Completeness	Timeliness	Relevance	Understandability	Accessibility	Consistency
Interface needs adapting to suit a mobile environment		X			X			X	
Can miss important information due to a lack of prompts	X	X	X	X					
Lack of drop-down categories; too many free-text fields; hard to know what information to enter and takes more time.	X	X	X						
Poor ability to locate an address using the Gazetteer; record may have been misspelled via free-text entry	X	X	X				X	X	X
The CIS system is not integrated with the incident management system, so both systems have to be updated separately	X	X	X	X	X			X	X

4.3 Mapping the data quality process

Based on the evidence so far, the aspects of the data quality monitoring process have been mapped against the key attributes of data quality (identified in Table 1), as shown in Table 4.

Table 4: Mapping of elements of data quality within the Constabulary to the main data quality issues

Data quality attribute within literature (based on evaluation in Table 1)	Definition	Data quality attribute within the Leicestershire Constabulary
Accuracy	The correctness of data with respect to real life	• On the whole accuracy is not apparent within the data quality monitoring process; main focus is on the completeness of fields within systems and that information is completed to a correct format (see below) but does not ensure that the information about a person is correct e.g. their correct date of birth or surname. • However, some users can request spellings of names and other details to be changed if they conduct a search and cannot find that person due to incorrect details
Completeness	The degree to which values are present in data collection and sufficient (Parker *et al*, 2006).	• Monitors the level of 'good', 'sparse' and 'bad' data held within the CIS • Icon within systems to ensure that data is entered into fields in the correct format
Timeliness	Whether the information is available in the required timeframe of the user (Forslund, 2007)	Not monitored within the Constabulary, but there is a maximum target of one day
Relevance	Whether the information addresses the users needs	Not monitored within the Constabulary
Understandability	The ease of comprehending the information (Al-Hamkin, 2007).	Not monitored within the Constabulary
Accessibility	Determines the degree to which information can be retrieved when required (Al-Hamkin, 2007).	Has been considered to some extent through the development of the Police National Database, which integrates information from several different systems
Consistency	Ensures that two or more data items do not conflict with each other (Al-Hamkin, 2007).	Not monitored within the Constabulary

From this mapping, it appears that the Constabulary are heavily focused on the attribute of completeness therefore monitoring the degree to which fields have been completed correctly and in the correct format. Other attributes, such as the accuracy of data therefore whether the correct information is held on a person; timeliness, relevance, understandability and consistency are not audited on a regular basis within the Constabulary.

The analysis of findings above is supported by results of the semi-structured interview. When questioned about the effectiveness of these data quality-monitoring processes, the MoPI manager explained that they do not ensure the correct details are entered into fields, such as the correct date of birth for a person. For example, entering the date of birth '1st January 2009' would meet the data standards but would not necessarily mean good data quality, as this might not be the actual DOB of the person. He suggested that the term data quality is difficult to define, as it can be a subjective term that means different things to different people, making it difficult to measure unlike common formats for data entry/ data standards. As a result, there are few processes in place to monitor the actual level of data quality. Since there is no definitive understanding of what data quality is and no specific measures, it was suggested in the interview that data standards are used instead as a comparative measure against other police forces. Umar *et al* (1999) recognise this issue within the telecommunications industry, and recommend the development of metrics that focus on measuring

the impact of data quality problems and the improvement of data quality problems, such as data reconciliation cost savings (such as labour costs) and performance (such as volume of errors).

5. Conclusion

This paper has investigated the impact that providing mobile access to information will have on the data quality of police information systems. Domains other than policing encounter issues with its data quality, such as inconsistency among systems, lack of standardisation and silos of information, but these are magnified in law enforcement due to the need to gather information and reapply it to new situations in the interests of public safety. Furthermore, the ability to directly input information into police systems within a time-pressurised mobile environment creates further ramifications for data quality.

The evidence from this study discourages the notion that UK police forces have sufficient measures to manage data quality within a mobile environment. At present, the completeness of data is only measured, and other measures of data quality including accuracy, timeliness, understandability and consistency are not considered. Since police officers can now input information directly via MDTs, this may cause vital links between items of data to be missed to the detriment of the vulnerable. It is recommended that the Constabulary agrees a definition of data quality and introduces some metrics to measure the quality of data within systems. Although this is a more subjective matter, if a common agreement is reached this might help to eliminate the level of subjectivity. Metrics could include those discussed in section 6.3.1, such as data reconciliation cost savings (such as labour costs) and performance (such as volume of errors). However, these conclusions are drawn from a small data set and future research might seek to validate this claim via collection of further evidence.

Inputting information into law enforcement systems is currently difficult due to the ineffective design of crime input-form interfaces, which does not take into account the limitations of entering data whilst attending compromising and dangerous situations. There are also several information systems that lack integration, causing duplication of data entry. These issues have implications for data quality within a mobile environment, as they serve as a potential source of error which may later jeopardise decision-making capabilities. To overcome these issues, it is recommended that future research focuses on approaches which address the design of an integrated input form for accurate and efficient entry of data. This remains an open question but possible approaches might include the development of controlled vocabularies to permeate the issue of entering data into free-text fields. In light of the introduction of the Police National Database in 2010, ensuring good quality data for nationwide decision-making purposes will become increasingly important on the research and law enforcement agendas.

The paper contributes to the existing small body of knowledge on data quality within a mobile policing environment. This knowledge can be applied by other law enforcement organisations looking to provide mobile access to their information and knowledge environment without reducing the level of data quality as a result of direct input of information.

References

Adler, M. & Ziglio, E. (1996) *Gazing into the oracle: the Delphi method and its application to social policy and public health*, Jessica Kingsley: London.

Al-Hakim, L. (2007) *Information quality management: theory and applications*, Idea Group Publishing, London.

Audit Commission. (2007) "Police data quality 2006/07: improving data quality to make places safer in England & Wales", [online] http://www.audit-commission.gov.uk/SiteCollectionDocuments/AnnualReports/2007/policedataquality2006_07REP.pdf.

Ballou, D. & Pazer, H. (1985) "Modelling data and process quality in multi-input, multi-output information systems", *Management Science,* Vol 31, No. 2, pp. 150-162.

Batini, C., *et al.* (2009) "Methodologies for data quality assessment and improvement", *ACM Computing Surveys,* 41(3), 16-52.

Baumber, S. (2007) *The IMPACT Nominal Index: an asset for child abuse investigators?,* MA dissertation, De-Montford University, United Kingdom.

Cappiello, C., *et al.* (2003) "Time-related factors of data quality in multi-channel information systems", *Journal of Management Information Systems,* Vol 20, No. 3, pp. 71-91.

Cellco, J. (1995) "Don't warehouse dirty data", *Datamation*, Vol 41, No. 19, pp. 42-52.

English, L. (2005) "Information quality: critical ingredient for national security", *Journal of Database Management*, Vol 16, No. 1, pp. 18-32.

Eppler, M. J. (2003) *Managing data quality*, Springer, New York.

Even, A. & Shankaranarayanan, G. (2009) "Utility cost perspectives in data quality management", *Journal of Computer Information Systems,* 50(2), 127-135.

Forslund, H. (2007) "Measuring information quality in the order fulfilment process", *International Journal of Quality & Reliability Management,* 24(5), 515-524.

Gendron, M. & D'Onofrio, M. (2001) "Data quality in the healthcare industry", *Data Quality*, Vol 7, No. 1, [online], http://www.dataquality.com/901GD.htm.

Huang, K., *et al.* (1999) *Quality information and knowledge,* Prentice-Hall, London.

Informatica. (2008) "Implementing data quality metrics and standards to enhance crime-fighting throughout the force's jurisdiction and beyond", [online], www.informatica.com/INFA_Resources/cs_humberside_police.pdf.

Lee, Y. W. (2004) "Process-embedded data integrity", *Journal of Database Management*, Vol 15, No. 1, pp. 88-103.

Lee, Y. W., *et al.* (2006) *Journey to data quality,* MIT, London.

Li, S. & Lin, B. (2006) "Accessing information sharing and information quality in supply chain management", *Decision Support Systems,* Vol 42, pp. 1641-1656.

Mayberry, M. (2002) "Data quality: before the map is produced", *Directions Magazine,* 8 September, [online], http://www.directionsmag.com/printer.php?article_id=250.

McLeod, J. & Hare, C. (2007) *How to manage records in the e-environment*, Routledge, London.

Miller, H. (1996) "The multiple dimensions of information quality", *Information Systems Management,* Vol 13, No.2, pp. 79-82.

Miller, H. (2005) "Information quality and market share in electronic commerce", *Journal of Services Marketing,* Vol 19, No. 2, pp. 93-102.

NPIA. (2007) "The management of police information (MoPI)", [online], http://www.npia.police.uk/en/8492.htm.

Olson, J. E. (2003) *Data quality: the accuracy dimension.* Morgan Kaufmann, London.

Orna, E. (2005) *Making knowledge visible: communicating knowledge through information products,* Gower, Aldershot, UK.

Parker, M. B., et al. (2006) "An evaluation of information quality frameworks for the World Wide Web", In: *8th Annual Conference on WWW Applications*, 6-8th September 2006, Bloemfontein, Free State Province, South Africa.

Redman, T. C. (2001) *Data quality: the field guide,* Digital Press, Oxford.

Redman, T. C. (1998) "The impact of poor data quality on the typical enterprise", *Communications of the ACM*, Vol 41, No. 2, pp. 79-82.

Shankaranarayanan, G. & Cai, Y. (2006) "Supporting data quality management in decision-making", *Decision Support Systems,* Vol 42, pp. 302-317.

Sheperd, E. & Yeo, G. (2002) *Managing records: a handbook of principles and practice*, Library Association, London.

Smith, K. (2007) Public sector records management, Ashgate, Aldershot, UK.

Umar, A., et al. (1999) "Enterprise data quality: a pragmatic approach", *Information Frontiers*, Vol 1, No. 3, pp. 279-301.

Wang, R. Y. & Strong, D. M. (1996) "Beyond accuracy: what data quality means to consumers", *Journal of Management Information Systems*, Vol 12, No. 4, pp. 5-34.

Xu, H., *et al.* (2002) "Data quality issues in implementing an Enterprise Resource Planning system", *Industrial Management & Data Systems,* Vol 102, No. 1, pp. 47-58.