An Integrated Framework for the Implementation and Continuous Improvement of Spatial Data Infrastructures

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Abstract
Development and usage of proper frameworks for implementation, evaluation and continuous improvement of spatial data infrastructures (SDIs) is currently an important research topic. A wide range of methods are being researched. In this respect, methods and techniques on performance measurement and evaluation techniques from business management literature are not yet considered. Some techniques and methodologies from business management literature could be developed based on Six Sigma, ABC (Activity Based Costing), BSC (Balanced Scorecard) and TQM (Total Quality Management). This article describes these techniques and then provides an integrated framework, based on these business management techniques, for implementation and continuous improvement of SDIs.

Key Words: spatial data infrastructure (SDI), Implementation, Continuous Improvement, Six Sigma, ABC, BSC, TQM.

1. INTRODUCTION

In recent years, many countries implement and develop NSDI (Masser, 2005a). Also, scientists suggest operational platforms for the SDI implementation such as SDI business model (Wagner, 2005), SDI partnership (Warnest et al., 2002) and spatially enabling governments (Masser et al., 2007). Considering the fact that SDI implementation is a matter of technical, technological, social, institutional, political issues and also financial challenges (Nedovic-Budic et al., 2004; Masser, 2005b; Mansourian et al., 2006; Onsrud, 2007), different aspects and perspectives must be brought into attention for the progress of SDI implementation. Moreover, considering various dimensions of an SDI as spatial data production issue, data accessibility, data sharing, updating, standardisation and institutional matters, the need for a structured and integrated implementation framework is inevitable.

The next significant and essential requirement for an SDI implementation is the performance measurement and the continuous improvement due to the complexity and long term procedure of SDI implementation. In an SDI, it is important to have feedback from different dimensions and perspectives and to improve the weak points in order to have an effective and operational SDI. Such improvements may help to decrease additional costs and will lead to high quality spatial data products. Furthermore, all SDI users as well as the whole society will be satisfied with standard, accessible spatial data products and delivery within a high performance SDI.

A variety of research is conducted in accordance with SDI evaluation and performance measurement (Georgiadou et al., 2005; Georgiadou et al., 2006; Kok and van Loenen, 2005; McDougall, 2006; Van Loenen, 2006; Najar et al., 2006; Giff and Lunn, 2008; Fernández and Crompvoets, 2008; Lance et al., 2006; Grus et al., 2007). However, few attention is paid to business management literatures which provide proper techniques for performance measurement and evaluation.

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In the business management literature, there are a variety of techniques which are used for continuous improvement of industries and/or organisational activities. Six Sigma, Activity Based Costing (ABC), Balanced Scorecard (BSC) and Total Quality Management (TQM) are some of these techniques that are also the targets of the article. Each of the mentioned techniques covers a dimension of SDI implementation. This article aims to address utilisation of these techniques as an integrated framework for implementation and continuous improvement of SDIs. Such integration will cover different aspects of SDI implementation and evaluation requirements. With this in mind, first, the techniques are reviewed briefly and then their feasible applicability for SDI implementation and evaluation is described.

2. CONCEPTUAL FRAMEWORK FOR SDI MEASUREMENT AND IMPLEMENTATION

In this section, we introduce a number of measurement methods used in the business management literature and describe their original purpose, then denote an integrated framework as an SDI implementation and evaluation procedure.

Six Sigma is a problem solving and continuous improvement method based on statistical methods where all the employees within an organisation have different roles within the entire technique. Six Sigma framework and guidelines can be used as a basic framework for SDI implementation.

Activity Based Costing (ABC) is a useful method to find the real price of the products according to the organisational costs and overheads. It also tries to assign costs to each activity and removes unnecessary and unprofitable tasks in an organisational process. ABC can be useful for estimating SDI costs as well as cost reduction and spatial data valuation.

Balanced Scoreboard (BSC) is a performance evaluation method used for evaluating and monitoring the strategic plans and the objectives. It can be used as an evaluation and monitoring method for SDIs and also for measuring the progress of SDI implementation according to different perspectives.

Total Quality Management (TQM) is a method to monitor the process quality. It deals with the entire product procedure and tries to keep the work process in a high standard. This method can be utilised as a proper technique for both quality control of SDI work process and spatial data.

Table 1 represents the usage domains and a description for various techniques discussed above. In the following sections, we will describe each method separately.

Table 1: A general overview of different business management methods.

Method	Key Premises
Six Sigma	Problem Solving and continuous improvement
ABC	Financial management and evaluation
BSC	Performance evaluation
TQM	Quality enhancement

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2.1 Six Sigma

Six Sigma is one of the most effective problem solving methodologies for improving business and organisational performance. It was first originated and introduced by Motorola Company in 1987 and targeted an aggressive goal of 3.4 parts per million defects (Barney, 2002; Folaron, 2003). The background of Six Sigma method is a statistical approach where two main items are discussed:

– the roll up of characteristic behaviours, and
– the natural increase of variation for each characteristic in the long term.

Here, the sigma scale is a universal measure of how well a critical characteristic performs compared to its requirements. It works in such a way that if sigma score increase, the characteristic will be more capable (Gygi et al., 2005). Six Sigma is using a scientific, structured method for business improvement that could be used for any aspect of organisation, process or person.

Six Sigma is defined as ''high-performance, data-driven approach to analyse the root causes of business problems and solving them'' (Blakeslee, 1999). Other persons described Six Sigma as a disciplined and statistically based approach for improving product and process quality (Hahn et al., 2000). Also, Six Sigma refers to a business process that allows organisations to improve drastically their bottom line by designing and monitoring everyday business activities in ways that minimise waste and resources while increasing customer satisfaction (Harry and Schroeder, 2000). To achieve these aims, Six Sigma involves all employees in the organisational activities, according to their skills, and also obtains their feedback for problem solving and continuous improvement of the processes. Solving complex and strategic problems is conducted through experts and professionals and moderate tasks are carried out via medium level of skill and average trained employees. The regular transactions are conducted by other staffs.

The Six Sigma methodology has two project strategies, DMAIC (Define, Measure, Analyse, Improve, and Control) and DMADV (Define, Measure, Analyse, Design, and Verify), which are describe bellow. These strategies are a set of standardised and systematic methods that each project has to use in order to have a continuous improvement.

2.1.1 DMAIC

DMAIC is a problem solving and continuous improvement strategy for any kind of organisational strategy. It includes the following steps (Gygi et al., 2005):

– Define: writes the problem statement context and project objective setting;
– Measure: understands the process and improves the baseline performance and capability of the process or system;
– Analyse: uses data and tools to understand the cause and effect relationships in the process or system;
– Improve: determines and develops the modifications that lead to a validated improvement in the process or system and tries to implement solutions to achieve the objective statement, and
– Control: establishes plans and procedures and implements processes control methods to ensure the improvements are sustained.

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To use this strategy, effective contribution of skilled and trained staffs, at different management levels, is essential. In other words, all employees have *fundamental* role for the DMAIC implementation. In addition, completing one step is a prerequisite for moving to the next step. After passing all steps successfully, a Six Sigma project is completed.

This strategy can be utilised for in an early stage of SDI implementation. In such situations, there are a number of initial tasks to start the SDI implementation procedure. Strategic plans, action plans, general objectives are some of the primary documents which have to be completed in the *define* step. Afterwards, within the implementation procedure of SDI, data production and delivery processes, collaboration among organisation for data exchange and also maintenance and standardisation of spatial data are measured and evaluated in the *measure* step. To perform this, integration of the Six Sigma measurement methods and the SDI evaluation indicators is suggested. *Analyse* deals with analysing the results of the measurements and identifying those barriers that impede SDI implementation and those positive points that facilitate the implementation. *Improve* enhances the procedures of SDI implementation regarding to the information derived from previous stage. Finally, *control* aims to check whether improvements of the previous steps caused the SDI implement in a proper way or not. As SDI implementation is a long term process, this methodology might be used many times as loop within the period of implementation.

2.1.2 DMADV

There are many similarities between DMADV and DMAIC. The major difference is in the last two letters which refer to *Design* and *Verify. Design* refers to either a new process or a corrective step to the existing one, eliminating the error origination that meets the target specification. *Verify* means verification by simulation of the performance of developed design and its ability to meet the target needs (Gygi, 2005). In DMADV, the processes change and redesign according to the customer's needs. Such change is needed in order to fit to the on demand requests instead of the improvement and control steps which more focus on readjusting and controlling by one way or other.

Although there are many overlaps in this strategy with the previous one, nations and societies which have already started an SDI implementation procedure and would like to extend or adjust it can use the DMADV strategy. In this strategy, the re-design of the SDI may extend or restructure the previous framework and then in the validate stage, it will be evaluated and monitored according to the new process and situation.

2.2 Activity Based Costing (ABC)

Financial aspects and cost are main features for SDI development. Even though the SDI budgets mainly stem from the government resources, these subjects are essential for the SDI managers to succeed in the spatial data market.

In the traditional way of management and accounting methods in the 1930s, corporate rules had a basic role to force companies for providing financial accounts. Although the application of strict rules was a proper way for financial accounts, management accounts were proposed as a decision-making tool in business atmosphere and therefore required more flexibility (Letza and Gadd, 1994). In such a method, production overhead was absorbed to the product cost to valuate the stock. Moreover, labour costs were used as a convenient overhead recovery base, although the ratio of the total labour cost was not proportional.

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However, the traditional methods often fail to incorporate the final cost today. The reason is that the technological costs and other overheads have increased rapidly, due to the expansion of global competition, and the increase of interactions via communication media, development of IT and access to inexpensive information systems. Therefore, new accounting methods such as Activity Based Costing (ABC) have been introduced.

ABC was first introduced in the late 1980s by Johnson and Kaplan (1987). Scientists expanded the first initial idea and developed a method for cost drivers to calculate activity costs for each product and service. They argued that such method supplies accurate cost data needed to make proper strategic decisions for product mix, sourcing, pricing, process improvement, and evaluation of business process performance (Cooper and Kaplan, 1992; Swenson, 1995).

ABC is a costing model which determines the activities in an organisation and assigns the cost of each activity resource to products and services separately regarding to the actual usage by each. It also generates the real cost of products and services by removing unprofitable activities and eliminate lowering prices of overpriced ones. Here, an activity is defined as a discrete task that a company makes in a product or service, and uses cost drivers to assign activity costs to products, services or customers related to these activities (Cooper, 1988; Ittner et al., 2002). In this method, products use activities and the activities use resources.

ABC has two main stages to assign overhead costs to products and services (Hilton, 2005). First, based on the definition, the main activities are determined and overhead costs are assigned to the activity cost pools according to the amount of resources used by activities. The activities are often derived from information gathered from interviews, questionnaires, and time cards (Cooper and Kaplan, 1991). The second stage contains cost allocation from each activity cost pool to each product line concerning to the amount of the cost driver utilised by the product line (Bjornenak and Mitchell, 2002). In other words, at the first step, organisational resources are grouped in the different pools such as salaries, license fees, operational costs and depreciation. Then, different institutional missions and tasks are grouped into homogeneous activities such as data preparation, research and development (R&D), data delivery (Ooi and Soh, 2003). In this way, each activity will use a percentage of a single or multiple cost pools. For example, the data preparation activity will use 10% of the rental cost, 20% of the salary and 40% of the operational costs.

As ABC reveals the links between performing particular activities and the demands those activities make on the organisation's resources, it provides managers with a clear picture of how products and services both generate revenues and consume resources. The profitability picture that emerges from the ABC analysis helps managers focus their attention and energy on improving activities that will have the biggest impact on the result.

An important part of SDI implementation are the financial and economical issues. A proper financial funding model may lead the SDI coordinators to a successful and operational SDI. Furthermore, having a clear idea about the SDI cost and the way of cost reduction will also increase the efficiency of SDIs. With this in mind, using the ABC method, main activities of SDIs are determined and according to the transparent implementation tasks, unprofitable and parallel activities will be eliminated. Also, in each step, the financial resources can be predicted with respect to different contributors

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whether the financial support is from the spatial data market or authorities. Moreover, for any task and process within a clear financial and economic perspective, evaluation and monitoring can be easily performed by the SDI coordinators.

2.3 Balanced Scorecard (BSC)

The success of the next generation of Spatial Data Infrastructures (SDIs) will, in part, depend on the ability of SDI coordinators to comprehend, analyse and report on the performance of their initiatives (Giff and Lunn, 2008). Therefore, it is necessary for SDI coordinators to use proper models and measuring techniques to assess and monitor the progress of SDIs.

BSC, as a technique from business management literature for strategic performance management, was introduced by Kaplan and Norton (1992) as a set of different measures that allow for a holistic, integrated view of business performance. It was a complementary solution for the traditional financial parameters to measure the performance in organisations. In other words, BSC is a performance measurement framework that provides an integrated look at the business performance of an organisation by a set of measures including both financial and non-financial metrics (Kaplan and Norton, 1992; Kaplan and Norton, 1996). Also, BSC refers to a multi-dimensional framework that uses measurement to improve an organisation's strategy.

There are some basic elements in the BSC structure which leads the strategy measurement in a proper way. A *perspective* is an element into which the strategy is decomposed to drive implementation. In most BSC structures, there are four perspectives: *financial*, *internal process, customer*, and *learning and growth*. As Norton and Kaplan (2000) mentioned, "Balanced Scorecards tell you the knowledge, skills and systems that your employees will need (learning and growth) to innovate and build the right strategic capabilities and efficiencies (internal processes) that deliver specific value to the market (customer) which will eventually lead to higher shareholder value (financial)". It is possible to add other perspectives or sometimes replace the mentioned perspectives according to the specific strategies. The perspective can be defined as an interpretation of the strategy in different dimensions.

The second main element of the BSC design is called *objective*. An objective is a statement of strategic intent, describing how a strategy will be made operational in an organisation. In other words, objectives are the main elements of the strategic plan and the entire strategy can be broke down into many objectives. In the BSC design, normally a limited number of objectives exist relating to one of the perspectives, which is normally described in one or two sentences.

The next basic element in a BSC design is the *cause and effect linkage*. In the BSC structures, objectives are related and depend on each other through cause and effect relationships. The cause and effect linkages are like *if – then* statements where the objectives in each perspective are linked with the graphical connectors according to the rules derived from different dimensions.

Another element of the BSC is the *measure* term, which is a performance metric one can calculate the progress of an objective. A measure must be quantifiable. In a BSC design there are reasonable numbers of measures explicitly linked to an objective. In addition, the measure concept is typically represented via mathematical formulas.

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The fifth element for BSC design is called *target*. A target is a quantifiable goal for the each measure. A combination of targets on the BSC design is the general goal of an organisation. They help the organisation monitor the progress toward strategic goals, and give proper feedbacks if necessary.

Strategic initiative is the last element of a BSC design. They are action programs that drive strategic performance and the activities which will lead the organisation to achieve the strategic results. All ongoing initiatives in an organisation should be associated with the strategy in the BSC.

BSC design can be used as an evaluation and monitoring framework for SDIs. By defining performance indicators as well as desired targets, for each objective, SDI coordinator and managers can measure a current situation, compare it with the target and then evaluate the progress of an SDI. Considering the four main perspectives in the BSC structure, BSC provides a general framework for evaluating SDIs from users' and data producers view point. It also helps to evaluate internal processes, financial affairs and even capacity building at the individual level. So BSC can be regarded as a general framework for an SDI evaluation.

2.4 Total Quality Management (TQM)

SDI implementation requires intra-organisational activities which imply that there are various hierarchical management decision making steps in different levels. Having a proper tool for increasing the quality of the entire procedure leads the SDI to succeed in not only high quality data production and management, but also in facilitating data sharing and access. Therefore, applying a quality management approach for the development of SDI is essential.

TQM consists of three main concepts. *Total* refers to the organisation (e.g., SDI organisation) and includes the whole supply chain and product life cycle. *Quality* means a high degree of excellence in products and also the comparison indicators with the existing standards. *Management* is the process of planning, organising, leading, coordinating, controlling and staffing (Fayol, 1966). TQM is a collection of principles, techniques, processes, methodologies, tools and best practices that over the time have been proven effective in order to increase the internal and external customer satisfaction with a minimum amount of resources.

Sashkin and Kiser (1993) defined TQM as an intense and long-term commitment to quality implementing such a commitment requires the use of tools and techniques. The commitment is more important than the way of utilising the method. TQM is a method to change the organisational values and beliefs in order to let everyone know the most basic aim which is the quality for the customer. Also the ways of working together are determined by what will support and sustain this basic aim (Sashkin and Kiser, 1992). On the other hand, they argued such a system as a shift in the way of thinking and the culture of an organisation rather than using a specific software, technique or specific tool (Sashkin and Kiser, 1993). TQM tools include quality training, process improvement, benchmark management, Statistical Process Control (SPC), Quality Control circle (QCC) and quality information computerisation (Huarng and Chen, 2002).

There are many scientists working to improve the TQM method. Edwards Deming (1986, 1993) introduced fourteen management principles as requirements to remain competitive in providing products and services. These include management commitment and leadership, statistical process control, removing barriers to employee partici-

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pation and control of their own quality, and continuous improvement of processes. Juran (1989) emphasised planning and product design, quality audits, and orienting quality management toward both suppliers and customers. Crosby (1984) focused on such organisational factors as cultural change, training, and leadership, and the ongoing calculation of quality costs. Important extensions to the TQM framework have included the development of customer-based specifications in the design of a product or process (Taguchi and Clausing, 1990), and benchmarking or the measuring of products/services and processes against those of organisations recognised as leaders (Camp, 1989).

TQM can be used as a general instrument for quality control of the SDI implementation procedures. To utilise such a technique in SDI, the fourteen step approach of Deming can be used in the SDI implementation procedure.

3. DISCUSSION

To investigate the applicability of the mentioned techniques for improving the development and maintenance of SDIs, this section investigates the pros and cons of each technique and their affects on SDI. Table 2 summarises the strength and weak points of each technique.

SDI is a collaborative effort: various organisations and institutions are involved in the development and implementation of SDI. Thus, team work and joint activities have a major role in arriving at the objectives of an SDI. One of the strengths of Six Sigma relates to team building and facilitating team working (see Table 2). This technique can be used for creating the collaborative environment, which is required for the development of SDI. In addition, to develop an SDI, different procedures (spatial data production and updating during daily businesses, inter-and intra organisational data sharing, managing databases and web services) have to be diffused within the organisations. Integrating human elements (culture change, user focus, spatial data-related responsibilities) with process elements (process management, measurement system analysis) can facilitate such diffusion. As highlighted in Table 2, 'integration of human and process elements' is another strength point of Six Sigma, which makes it a suitable technique in the work with implementing SDI.

With respect to the weak points of Six Sigma, 'the need for high quality data for the evaluation' can be considered as the weakness of the most evaluation and improvement methods. Also, since the priority of major activities for implementing an SDI is generally clear, so 'the prioritisation of projects' (Table 2) is not too critical for using Six Sigma for SDI implementation and continuous improvement.

Financial management of SDI is a complex task. Due to diversity of activities required for implementing an SDI, calculating the costs associated for each activity as well as relevant overheads calls for adopting proper financial frameworks. The framework should also provide the possibility of monitoring SDI funding for each activity, based on the mentioned estimations. ABC with the advantage of 'clarification and calculation of the real cost for the products, services, processes and distribution channels' and 'supporting performance measurement' (Table 2) can satisfy such an SDI's requirement. ABC is also easy to understand and well integrated with Six Sigma.

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Table 2: Strengths and weaknesses of discussed methods according to the SDI.

Method	Strengths	Weaknesses
Six Sigma	– Team Building and Facilitation – Integration of the human and process elements	– Requiring quality data available for the measurement – Prioritisation of projects is critical
ABC	– Easy to understand – Accurate measurement of costs – Well integration with Six Sigma and other continuous improvement tools – Supports performance measurement and scorecard – Enables costing processes	– Time consuming for data collection – ABC implementation cost
BSC	– The ability to link: o Financial and non-financial indicators o Internal and external aspects o Performance drivers and outcomes – Organising disparate data, and providing benchmarks for management discussion and operations. – Highlighting inevitable trade-offs	– Higher weight of financial measure
TQM	– Encourages effective participation	– Requires much time and effort

Two weak points of ABC, mentioned in Table 2, might not be critical from an SDI perspective as:

– 'time consuming for data collection' is the limitation of the most monitoring and evaluation approaches, not specifically for ABC, and
– ABC implementation cost will be a small percentage of the financial resources required for the SDI implementation.

Due to complex and multi-dimensional nature of the SDI development, its evaluation and monitoring should be based on a multi-view framework linking financial and non-financial indicators, internal and external aspects, and performance drivers and outcomes. BSC not only has the advantage of linking the mentioned factors, but also can highlight inevitable trade-off among them. Therefore, BSC can be a proper framework for the implementation and evaluation of SDIs.

Regarding the weakness of BSC, from an organisational perspective, a financial measure has much greater organisational weight than its new non-financial sibling. However, in SDI, besides financial benefits of spatial data sharing, non-financial benefits of spatial data usage in decision making and planning is also of high value. Furthermore, social benefit gained from SDI has more weight than any financial indicator. Governments spend much money for SDI development to promote the society and better life for citizens, so the financial perspective is important, but not the most significant dimension of SDI implementation.

Finally, TQM encourages effective participation by involving people in the decision making process for development of SDI and improving the quality of their work environment provides them with a sense of value and purpose. Similar to the other methods, TQM is also a long-term procedure and implementation of TQM takes too much time and effort.

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With respect to this description, the mentioned techniques can be used for different aspects of SDI implementation, monitoring and improvement.

4. CONCLUSIONS

This article proposes instruments and frameworks from the business management field for the implementation and evaluation of SDIs. We first reviewed different strategic and continuous improvement methods including Six Sigma, ABC, BSC and TQM. Then the applicability of each technique for the implementation of SDI was investigated. The primary investigation shows that each of these techniques can be used in some aspects of SDI implementation. In a nut shell, an integrated general framework for the SDI implementation consists of the Six Sigma as a core methodology. For implementing an SDI, the DMAIC (Define–Measure–Analyse–Improve–Control) approach can be used; ABC (Activity Based Costing) for economic management of SDI; BSC (Balanced Scorecards) for monitoring the progress of SDI and TQM (Total Quality Management) for the quality management of the entire procedure of SDI implementation.

Table 3 illustrates the summary of the usages and value of each method for SDI implementation and continuous improvement.

Table 3: Summary of the usage and value for SDI from discussed methods.

Methods	Value for SDI (Where it can be used)	Usage Domain
Six Sigma	A general framework for the SDI Implementation	Core methodology
ABC	Economic management and evaluation of SDI	Define, Measure, Improve
BSC	Monitoring the progress of SDI	Measure, Analysis, Control
TQM	Quality management of the whole procedure of SDI implementation	Measure, Analysis, Improve, Control

It is worth to be noted that the discussed techniques are originally used for business management and continuous improvement within an organisation. However, also for the implementation of SDI with its collaborative and intra-organisation nature, applying these techniques may be beneficial and worthwhile to be considered by the SDI community.

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REFERENCES

Barney, M. (2002). Motorola’s second generation. *Six Sigma Forum Magazine,* 1(3): 13-16.

Bjornenak, T. and F. Mitchell (2002). The development of activity-based costing journal literature, 1987-2000. *European Accounting Review*, 11(3): 481-508.

Blakeslee, J. (1999). Implementing the Six Sigma solution, *Quality Progress,* 32(7): 77-85.

Camp, R. C. (1989). *Benchmarking: The search for industry best practices that lead to superior performance*. Milwaukee, WI: Quality Press.

Cooper, R. and R. Kaplan (1992). From ABC to ABM, *Management Accounting*, 74: 54-57.

Cooper, R. and R. Kaplan (1991). Profit priorities from activity based costing, *Harvard Business Review,* 69(3): 130-135.

Cooper, R. (1988). The rise of activity-based costing – part two: when do I need an activity-based costing system? *Journal of Cost Management* (fall) 2(3): 41-48.

Crosby, P. B. (1984). *Quality without tears: The art of hassle-free management*. Milwaukee, WI: Quality Press.

Deming, W. E. (1993). *The new economics for industry, government, education*. Cambridge, MA: Massachusetts Institute of Technology, Center for Advanced Engineering Study.

Deming, W. E. (1986). *Out of the Crisis*. Cambridge, Massachusetts Institute of Technology: Center for Advanced Engineering Study.

Fayol, H. (1966). Administration industrielle et générale - prévoyance organisation-commandement, coordination – contrôle, Paris: Dunod.

Fernández, T.D. and J. Crompvoets (2008). "Evaluating Spatial Data Infrastructures in the Caribbean for sustainable development", *Proceedings of the 10th GSDI conference*, February 25-29, 2008, St. Augustine, Trinidad.

Folaron, J. (2003). The evolution of Six Sigma. *Six Sigma Forum Magazine,* 2(4): 38-44.

Georgiadou, Y., Rodriquez-Pabón, O. and Lance, K.T. (2006). Spatial data infrastructure SDI and e-governance: a quest for appropriate evaluation approaches, *URISA journal*, 18(2): 43-55.

Georgiadou, Y., Puri, S.K. and S. Sahay (2005). Towards a potential research agenda to guide the implementation of spatial data infrastructures - A case study from India, International Journal of Geographical Information Science, 19(10): 1113-1130.

Giff, G. and R. Lunn (2008). "Designing Performance Indicators for Local SDI Assessment: A City of Fredericton Case Study", *Proceedings of the 10th GSDI conference*, February 25-29, 2008, St. Augustine, Trinidad.

Grus, L., Crompvoets, J.W.H.C. and Bregt, A.K. (2007). Multi-view SDI assessment framework, *International Journal of Spatial Data Infrastructures Research*, 2: 33-53.

Gygi, C., DeCarlo, N., Williams, B., Stephen and R. Covey (2005). Six Sigma for Dummies: For Dummies.

Hahn, G.J., Doganaksoy, N. and R. Hoerl (2000). The evolution of Six Sigma, *Quality Engineering*, 12(3): 317-26.

Harry, M.J. and R. Schroeder (2000). *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, New York: Doubleday.

Hilton, R.W. (2005). *Managerial Accounting: Creating Value in Dynamic Business Environment*, New York: McGraw-Hill Irwin.

Huarng, F. and Y.T. Chen (2002). Relationships of TQM philosophy, methods and performance: A survey in Taiwan, *Industrial Management+Data systems*, 102(3/4*):* 226-234.

Ittner, C. D., Lanen, W. N. and D. F. Larcker (2002). The association between activity-based costing and manufacturing performance, *Journal of Accounting Research*, 40: 711-726.

Johnson, H. and R.S. Kaplan (1987). *Relevance Lost: the Rise and fall of Management Accounting,* Boston, MA: Harvard Business School Press.

Juran, J. M. (1989). *Juran on leadership for quality: An executive handbook*. Wilson, CT: Juran Institute.

Kaplan, R. S. and D. P. Norton (2000). Having trouble with your strategy? Then map it, *Harvard Business Review,* 78(5): 167-176.

Kaplan, R.S. and D.P. Norton (1996). Using the balanced scorecard as a strategic management system, *Harvard Business Review*, 74(1): 75-85.

Kaplan, R.S. and D.P. Norton (1993). Putting the balanced scorecard to work, *Harvard Business Review*, 71(5): 43-2.

Kaplan, R.S. and D.P. Norton (1992). The balanced scorecard: measures that drive performance. *Harvard Business Review*, January–February: 171-9.

Kok, B. and B. van Loenen (2005). How to assess the success of National Spatial Data Infrastructures? *Computers, Environment and Urban Systems*, 29: 699-717.

Lance, K.T., Georgiadou, Y. and Bregt, A. (2006). Understanding how and why practitioners evaluate SDI performance, *International Journal of Spatial Data Infrastructures Research*, 1: 65-104.

Letza, S. and K. Gadd (1994). Should activity-based costing be considered as the costing method of choice for total quality organizations? *The TQM Magazine*, 6(5): 57-63.

Mansourian, A., Rajabifard, A., Valadan Zoje, M.J. and I. Williamson (2006). Using SDI and web-based systems to facilitate disaster management, *Journal of Computers and Geosciences*, 32: 303-315.

Masser, I., Rajabifard, A. and I. Williamson (2007). Spatially enabling governments through SDI implementation, *International Journal of Geographical Information Science*, 22(1): 5-20.

Masser, I. (2005a). “Some priorities for SDI related Research”, *FIG Working Week 2005 and GSDI-8*, Cairo, Egypt April 16-21, 2005.

Masser, I. (2005b). “The Future of Spatial Data Infrastructures”, *ISPRS Workshop on Service and Application of Spatial Data Infrastructure*, XXXVI (4/W6),14-16 Oct 2005, Hangzhou, China: pp. 7-15.

McDougall, K. (2006). A Local-State Government Spatial Data Sharing Partnership Model to Facilitate SDI Development, The University of Melbourne.

Najar, C., Rajabifard, A., Williamson, I. and C. Giger (2006). “A Framework for Comparing Spatial Data Infrastructures: An Australian-Swiss Case Study”, *Proceedings of GSDI 9 - International Conference for Global Spatial Data Infrastructure*, 3-11 Nov 2006, Santiago, Chile.

SDI Convergence. Research, Emerging Trends, and Critical Assessment. B. van Loenen, J.W.J. Besemer, J.A. Zevenbergen (Editors).
Nederlandse Commissie voor Geodesie Netherlands Geodetic Commission 48, 2009.

Nedovic-Budic, Z., Feeney, M.E.F., Rajabifard, A. and I. Williamson (2004). Are SDIs serving the needs of local planning? Case study of Victoria, Australia and Illinois, USA, *Computers, Environment and Urban Systems*, 28: 329-351.

Onsrud, H. (ed.) (2007). *Research and Theory in Advancing Spatial Data Infrastructure Concepts*, ESRI Press: Redlands, California.

Ooi, G and C.Soh (2003). Developing an activity-based costing approach for system development and implementation, *SIGMIS Database*, 34(3): 54-71.

Sashkin, M. and K.J. Kiser (1993). *Putting total quality management to work*. San Francisco: Berrett-Koehler.

Sashkin, M. and K.J. Kiser (1992). *Total quality management assessment inventory*, Seabrook, MD: Ducochon Press.

Swenson, D. (1995). The benefits of activity-based cost management to the manufacturing industry, *Journal of Management Accounting Research*, 7: 167-180.

Taguchi, G. and D. Clausing (1990). Robust quality, *Harvard Business Review*, 68(1): 65-75.

Van Loenen, B. (2006). Developing geographic information infrastructures, the role of information policies. PhD thesis, Delft University of Technology, Delft, the Netherlands.

Wagner, R.M. (2005). “Need for a Framework SDI Business Model”, *Joint EuroSDR/ EuroGeographics Workshop*, BKG Frankfurt, Germany, 23-25 February.

Warnest, M. and Rajabifard, A. and I. P. Williamson (2002). “Snapshot of SDI Development in Australia: Models, Partnerships and Lead Agencies Advancing Implementation”, *Proceedings of Joint AURISA and Institution of Surveyors Conference*, Adelaide, South Australia.

SDI Convergence. Research, Emerging Trends, and Critical Assessment. B. van Loenen, J.W.J. Besemer, J.A. Zevenbergen (Editors).
Nederlandse Commissie voor Geodesie Netherlands Geodetic Commission 48, 2009.

SDI Convergence. Research, Emerging Trends, and Critical Assessment. B. van Loenen, J.W.J. Besemer, J.A. Zevenbergen (Editors).
Nederlandse Commissie voor Geodesie Netherlands Geodetic Commission 48, 2009.