# Towards a Stage Model for GIS and SDI Deployment in Local Government

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**Abstract**

*This paper focuses on the deployment of Geographical Information Systems (GIS) and Spatial Data Infrastructures (SDI) within local government in Thai Provinces. GIS has been used extensively within local government and many countries have undertaken SDI initiatives, but these tend to focus at the national level, failing to address the local deployment issues. By their nature as infrastructures, an SDI displays different diffusion patterns to GIS, as they exhibit network externalities and extend an 'installed base'. Having described the GIS and SDI concepts, the authors subsequently turn to the Stage Model literature, which has been applied to generic Information Systems and GIS. An assimilation of this literature is presented and an extended model is proposed, which can be applied in a prescribed manner, aiding in the deployment of GIS and SDI within local government.*

**Keywords**: GIS, SDI, local government deployment model

## 1. Introduction

In Europe, as in many other parts of the world, the use of geographical information systems (GIS) to support local and national government is widespread and growing. Since the 1990s a growing number of countries and regions have sought to extend the capabilities of GIS, by developing and implementing spatial data infrastructures (SDIs), to facilitate access to timely, reliable and appropriate spatial data, and to provide regulatory, fiscal and other broader contexts for the use of these technologies.

Thailand is one country where work is currently underway for the development of a SDI at the national level. Take-up and use of GIS and related technologies within Thai provincial governments, meanwhile, is extremely mixed, with some provinces being well advanced in the process and others barely at the initial stages. The EU-funded project "Spatial Data Infrastructures and GIS Applications for Thai Local Government" (SAGIS-LoG) seeks to assist development of appropriate spatial data infrastructures and GIS applications for Thai local governments, through a sharing of ideas, concepts and know-how.

A growing body of literature and case studies allows comparison of alternate models of GIS diffusion to and use within government departments, and provides guidelines for the introduction of these technologies to public-sector organisations. In contrast, few guidelines yet exist to assist adoption of SDIs, and those that have been published so far, such as the GSDI Cookbook (Nebert, 2001), tend to focus on the technical rather than the human and organisational aspects of the task. Early in the SAGIS-LoG project, it became clear that these human, rather than technical, factors would be the critical ones to be addressed if GIS and SDI take-up in Thailand were to succeed.

A theoretical base gleaned from the Corporate Information Infrastructure literature (Ciborra, 2000) has allowed development of an analytical framework (Hayes et al., 2004) for SDI that acknowledges the profound impact of the "installed base", and stresses the need for bottom-up alignment, sensitivity towards the disenfranchised 'angry orphans,' and resolution of tensions between 'global' and 'local' (Star and Ruhleder, 1996; Rolland, 2000). Leading on from this analytical framework, work is now underway towards developing a model to identify, describe and guide successful achievement of key stages in the evolution of an SDI for Thai local governments. The present paper explains the rationale behind this approach, and outlines the key features of the emerging stage model.

## 2. Geographical Information Systems and Spatial Data Infrastructures

In most countries, local governments serve as branches of the national government. They generally promote three interests of their local communities, including the social, economic, environmental, recreational, cultural, and/or general development of the region. Typically, these functions will break down into the broad categories of: housing; town and country planning; roads and other transportation infrastructures; water supply and sewerage; development incentives and controls; environmental protection including rivers, lakes, air and noise; recreation facilities and amenities; agriculture; education; and health and welfare (see, e.g., Oasis, 2005)

Virtually all these activities require the collection, storage, management, analysis and presentation of information with a location element attached to it. An often-quoted statistic claims that as much as 80% of all local government decisions are of a spatial nature (FGDC, 1996). However, while local (and national) governments have always used geographic information, they have rarely used it effectively or efficiently. Typical problems include redundancy and duplication of effort; problems of update and version management; excessive reliance on out-of-date data; issues of security, data quality, confidentiality, and rights to privacy, etc.; time wasted on routine (often repetitive and boring) tasks; and, especially, a poor or non-existent culture of sharing information between departments, let alone between organisations.

Recognition of these problems has led a growing number of local authorities to adopt geographical information systems (GIS) as key components of their information management strategies. GIS combines digital mapping with spatially-enabled databases and analytical tools, to assist extraction and effective use of geographical information from spatial data. These systems originated in North America and Europe in the 1960s, initially as a means of adding spatial search-and-retrieval capabilities to geographic databases (see Figure 1). In the intervening four decades, GIS have evolved to include an ever-broadening range of functionality, including tools for scenario-testing and decision-support, wider integration of data, and publication of information across the Internet and to mobile devices (cell phones, etc.) phenomenon.

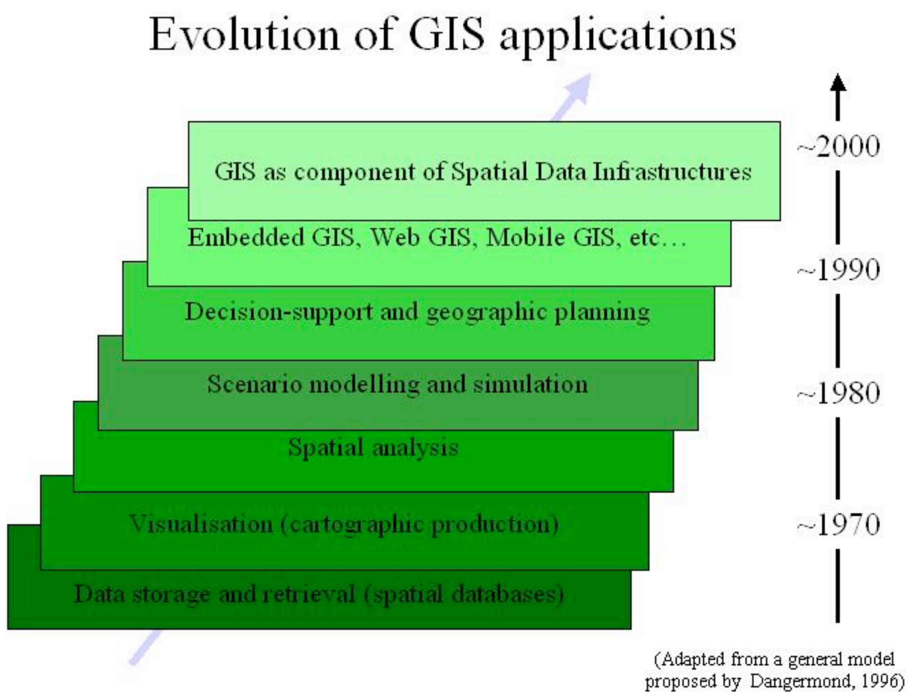



**Figure 1 - Evolution of GIS applications**

Today, GIS is one of the fastest-growing branches of information technology, with a global market in 2004 estimated to be worth at least US$2.02 billion (Daratech, Inc., 2004). Governments at all levels account for a significant slice of this budget: according to Craglia and Masser (1993 p.1) "the largest users of GIS technologies in Europe are central and local government agencies... In countries such as Germany and Great Britain, local government GIS applications probably account for between a quarter and a third of the total market."

However, having access to GIS technologies is increasingly found to be insufficient for effective working in the globalised world. Efficient application of GIS, particularly in the public sector, requires ready access to reliable, good-quality spatial data; it requires regulatory and fiscal frameworks that encourage interaction and communication of information and ideas between – and even within – government departments; and it needs suitably skilled personnel to work with these tools. In short, it requires establishment of spatial data infrastructures (SDIs) to provide “the matrix of technologies, policies and institutional arrangements that will facilitate the availability of, and access to, spatial data for all levels of government, the commercial sector, the non-profit sector, academia and citizens in general." (GSDI, 2000; see also Onsrud, 1998).

The SDI concept initially emerged in Canada in the 1980s (Groot and McLaughlin 2000), and was subsequently developed and formalised in the United States with a Presidential Executive Order (Clinton 1994) in the early 1990s. Since then a growing number of initiatives have been launched to develop SDI policies and implementations at different organisational levels and geographic scales, ranging from the global (GSDI 2000, 2001, 2004), through regional (e.g. Infrastructure for Spatial Information in Europe Initiative (INSPIRE, 2002)) to national levels (e.g. the Irish Spatial Data Infrastructure, see McCormack, 2003 and Matthews, 2004, and its Thai counterpart, as documented in Silapathong, 2004).

A key feature of all SDIs is their hierarchical nature (Chan and Williamson, 1999; Rajabifard et al, 2003) (see Figure 2). Viewing SDI as hierarchies explicitly recognises the complex vertical relationships between SDIs, as well as the equally-important (Rajabifard *et al,* 2003) horizontal relationships that exist between SDIs at any one level. As was pointed out by Hayes *et al* (2004), the need for these multiple levels of SDI development to be consistently integrated has often been overlooked. This is regrettable, since the establishment of SDIs is most likely to succeed when they engage all levels, from the local, through regional and national, to the international or global (Annoni *et al.* 2002, Craglia *et al.* 2003).

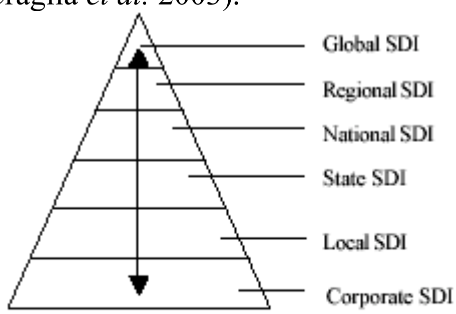



**Figure 2 - The SDI hierarchy (Rajabifard *et al.* 2000)**

### 2.1 The Diffusion of GIS and Patterns of SDI Adoption

Numerous studies have examined the manner in which GIS have diffused into and have been implemented within society (e.g. Onsrud and Pinto, 1991; Obermeyer and Pinto, 1994; Masser and Campbell, 1994; Campbell and Masser, 1995; Masser et al, 1996). Most of these are based on the "assumption that GIS should be regarded as a form of technology and perhaps more particularly as an innovative technology" (Campbell, 1996: 26). From such a perspective, 'diffusion' is seen as "the fundamental process that is responsible for the transfer of innovations from the workshops of their inventors to becoming a daily part of the lives of a large section of society" (Campbell and Masser, 1995: 4).

There have as yet been no comparable studies of the diffusion and adoption of SDI. In part, this may be due to the relative infancy of the SDI concept, compared to that of GIS, but it also requires different approaches to those adopted for GIS diffusion studies.
The primary *raison d'être* of a spatial data infrastructure is to encourage and facilitate cooperation and interoperability between technologies, between multiple participants and stakeholders, and within as well as between a diversity of organisations. It is, thus, a paradigm, a framework exhibiting network externalities (Shapiro, 1999) and a conceptual foundation for integration, rather than a technology *per se*.

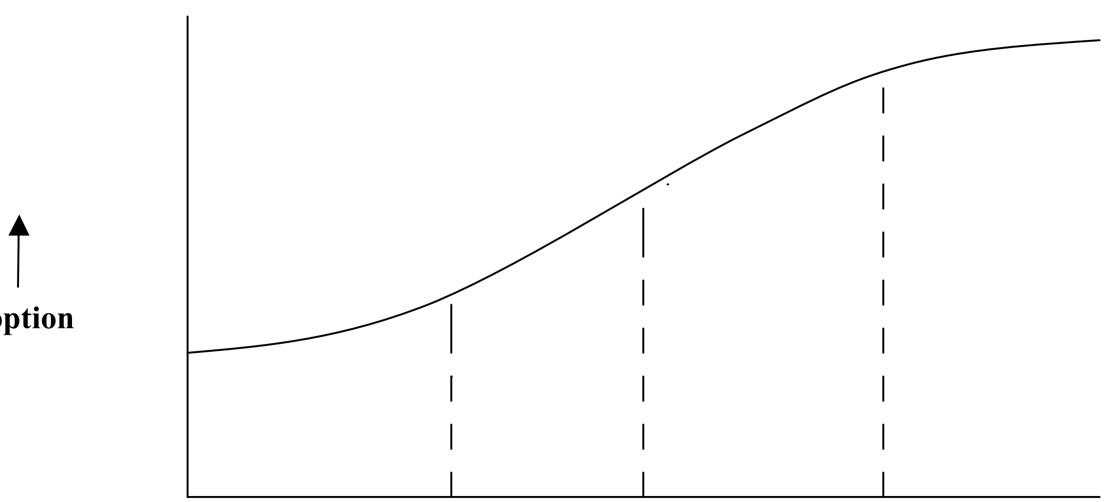
According to Monterio and Hanseth (2004) information infrastructures involve large communities and open, socio-technical networks. They are not designed from scratch, but evolve through the "cultivation" of a shared, open, socio-technical, heterogeneous installed base. Hanseth (2004) also stresses that "establishing a working information infrastructure is a highly involved socio-technical endeavour". In fact, infrastructures cannot be designed in the same manner as information systems (Star, 1996, Ciborra, 2000), since there is never a 'new' infrastructure. Instead new developments extend, integrate into or improve existing infrastructures (Ciborra, 1998), and large infrastructures will normally only evolve slowly, due to the inertia of this installed base (Ciborra, 2000).

Achieving the necessary interplay among multiple actors, stakeholders and technologies requires careful choreography and strategic planning. Each participating organisation is likely to undergo substantial changes in their own internal structure and working practices; while, over and above the processes internal to any one participant, regulations and standards also have to be designed, implemented and adopted to complement the technology. That is, the development and expansion of an SDI is less a question of "diffusion," and more one of encouraging or persuading individual actors and stakeholders to "buy in" to the evolving system.

## 3. Evolution of Stage Models

This section provides a discussion on Nolan's Stage Model Theory. This includes a description of the organisational situation during each stage, the side-effects of actions taken by management in relation to their computer resource and the factors that cause a transition from stage-to-stage.

**Adoption**



**Stage One** **Stage Two** **Stage Three** **Stage Four**

**(Initiation)** **(Contagion)** **(Control)** **(Integration)**

**Figure 3 - Nolan's Stage Model**

*Stage Theory* in Information Systems development first originated with Nolan (1973), whose ideas were driven by the struggle that organisations faced with managing the ever-expanding computer resources at their disposal. Using a graphic representation, of the computer budgets of three organisations over a time period as a quantitative measure, Nolan identified a common pattern (i.e. "S-shaped") amongst the three organisations. This pattern represents four distinct stages which are shown as a graph in Figure 1. Stage One is associated with slow annual increases (in budget) after computer acquisition, Stage Two is linked with highly increasing annual increases, Stage Three is connected with decreasing annual increases or decreases from the previous year and Stage Four is associated with slow, even annual increases. These contrasting rates of increase and plateau in costs form the "S-shape" of the graph mentioned above.

Stage One - *Initiation* pertains to the organisation's purchase of a computer for efficiency and for computational reasons. Due to high fixed-cost of this purchase, the company are eager to derive maximum utilisation of the computer. The problems of Stage One give rise to the emergence of Stage Two -*Growth*, the reason for which are managerial actions whose aim is to encourage alienated users to investigate the potential of computing. This stage is characterised by managerial commitment to the computing function. Management's aim at this stage is use up any excess capacity of the computer. However, this is realised without careful planning and control. This leads, inevitably, to saturation of the computer's capacity, resulting in larger and expanded computer systems and recruitment of highly-trained, specialised people at high salaries. These steps cause the dramatic increase in the computer budget, to a point of crisis for management. In Stage Three – *Control*, this crisis is remedied by establishment of steering committees who plan and set priorities, centralising of computer activities, standards in programming and budgetary controls/cost justification.
Stage Four - *Integration* takes the control process further by aligning the computer resources with business needs. Two stages were added to the Growth Model (King and Kramer, 1984). Management's attitude was said to be more about the control of organisational data resources as opposed to computing resources (brought about by database management systems). This gave rise to a new stage called *Data Administration*, which eventually was superseded by the sixth stage; *Maturity*. This stage represented the argument that the state of computing at any time was the balance between technical change and managerial control policies (i.e. Equilibrium Model).

King and Kramer (1984) outline six weaknesses with Nolan's Growth Model. These include the representation of an organisation's computer resource by computer budgets, the assumed driving of computing growth by technological change, the assumption that organisational goals are shared by managers, the question whether computing knowledge is as easy to acquire as the model suggests, the premise that managers have an idea of which direction computing is taking and lastly, the assumption that changes in computing assumes a continuous manner.

As Prananto et al (2001) point out, that despite criticism, the stages of the growth model is a "popular framework for describing the patterns of organisational information systems". It finds use as a good descriptor of where an organisation lies in terms of its information systems maturity and also prescribes in which direction an organisation should go with respect to information systems.

### 3.1 IS Adoption of Stage Models

Nolan's Stage Model Theory and Stage Model Theory has been widely adopted within the IS literature. Damsgaard et al (2000) draw on Nolan's Growth Model with a view to building a four-stage growth model for intranet implementation and management. Kanzanjian et al (1989) introduce a four stage growth model for technology based new ventures (TBNVs). Piccoli et al (2003) present a five-stage model for explaining and predicting the development of a firm's Web site design and functionality. Lientz and Chen (1981) propose a four-stage approach for assessing new information technology.

### 3.2 GIS Stage Models

This section highlights how Nolan's Stage Model Theory has been applied in the field of Geographical Information Systems. Tomaselli (2003) proposed a model for GIS, which describe the five stages of GIS development. Stage One is *GIS Interest and Awareness.* In this stage, for a GIS to get started in an organisation, the GIS need a *champion* or *implementer.* As a champion has more influence in the organisation, any GIS initiated by him/her is said to be a "top-down" implementation. Alternately, any GIS proposition by an implementer is seen as a "bottom-up" implementation. In Stage Two, *GIS Development Begins,* a single, large project is undertaken with the help of an outside consultant, if it is a "top-down" implementation. If the implementation is "bottom-up", the GIS starts with small projects surrounding the mid-manager's (implementer's) work.

Stage Three, *GIS Acknowledgement*, describes when the GIS start getting the attention of the rest of the organisation. The champion is much more visible within the organisation, so therefore does the implementer needs the get the support of a champion? The proof that the organisation has reached this stage is when the organisation has at least one staff member assigned to GIS issues. However, certain factors such as budget cutbacks, the hiring of the wrong person for the GIS job and the leaving of the organisation by the champion can result in the GIS being scrapped.

The fourth stage, *GIS Support Expands,* more and more champions emerge in the top level of management. This is due to more projects being completed and the recognition of benefits to the organisation. More GIS staff is recruited from within and without the organisation. However, much duplication exists, as departments are reticent to share data and there is also a problem with departments using different applications that are incompatible with other departments. The fifth stage, *Organisational Integration: Enterprise GIS* is the realisation of organisation-wide implementation of GIS, whereby cooperation is achieved between departments. This is the result of a critical mass of champions, implementers and users being reached.

Marr et al (1996) provides a model assessing the GIS maturity in organisations which is derived from Nolan's Growth Model and from the interpretation of processes commonly undertaken in the conversion to GIS by New Zealand local authorities. With the use of statistical analysis techniques, a comparison was made by the authors as to which organisations have the greater level of GIS maturity. This was based on the number of uses (of GIS), departments (using GIS) and age (of GIS). This model can be used to assess an organisation's progress in relation to other comparable authorities. Their analysis showed that over half of the organisations assessed had achieved "Fully Integrated GIS" and had identified "Corporate Data Integration" as the next step in their development.

| Stages | Feature of IS/GIS Implementation | Similarity Across Models |
|---|---|---|
| Stage 1: Early implementation Stage | Need for a Champion/Implementer in the Organisation (Damsgaard; 2000; Kanzanjian; 1989, Tomaselli; 2003) | ◑ |
| | Attention of Management (Nolan; 1973; Tomaselli; 2003) | ◔ |
| Stage 2: Growth Stage | Managerial Commitment (Nolan; 1973) | ◔ |
| | Organisation eager to extract value from the system in the initial stages (Nolan; 1973; Piccoli; 2003) | ◔ |
| | Saturation of a Computer's Capacity (Nolan; 1973) | ◔ |
| | Need to extract a critical mass of users initially (Damsgaard; 2000; Tomaselli; 2003) | ◔ |
| | During implementation, growth will be experienced by the organisation in terms of sales, employees and costs (Nolan; 1973; Kanzanjian; 1989) | ◔ |
| Stage 3: Control Stage | Need for planning and control (Nolan 1973; Damsgaard 2000; Kanzanjian 1989, Piccoli 2003; Tomaselli 2003; Chan 2000) | ◕ |
| | Establishment of a Steering Committee (Nolan 1973; Tomaselli 2003) | ◔ |
| | During implementation, functional departments evolve/change forming a new hierarchy (Nolan 1973; Kanzanjian 1989) | ◔ |
| | Implementers move to a training/support capacity. | ◔ |
| | More implementers are created. | ◔ |
| Stage 4: Stability | Alignment of the computer resource with organisation's needs (Nolan 1973; Damsgaard 2000; Marr 1996; Kanzanjian 1989; Lientz 1981; Tomaselli 2003; Chan 2000) from which stability will result (Kanzanjian 1989; Nolan 1973; Piccoli 2003) | ● |
| Stage 5: Data Administration | Need for balancing technological advancement and efficiency in the computing resource (Nolan 1973; Lientz 1981) | ◔ |
| | Control and administering of the data resources associated with the implementation (Nolan 1973; Damsgaard 2000; Marr 1996) | ◑ |

**Table 1: Similarities across the Various Stage Models**

Note: ○ No support ◔ ◑ ◕ ● strong support

Chan et al (2000) present a three-stage approach to the long-term development of a corporate GIS. In the first stage, a module of business process GIS (i.e. GIS modules which have the function of directly generating the products and/or services required of the organisation) is developed to generate direct and immediate business benefits to the organisation. This stage serves to raise the awareness of GIS in the organisation, and to demonstrate the value of GIS. In the second stage, top management funding and policy guidance are secured. The objective at this stage is to build a robust, over-arching framework to guide GIS development in the organisation later on. In the third stage, the emphasis of development of the corporate GIS is shifted from building the centralised entity to building GIS capabilities in business units. These are based on the over-arching framework introduced in the second stage.

## 4. Towards a GIS/SDI Deployment Model

Having assimilated IS/GIS Stage Model characteristics, the following model is proposed as a pro-active checklist which allows GIS champions /implementers to encourage and stimulate adoption of GIS. Table 1 summarises the findings on organisational stage management of the computing resource and highlights the similarities across each of the models. Figure 4 shows the key elements described in the assimilation of stage models (Table 1), but extends these taking into account the infrastructural aspects of SDI and the external influences. An SDI initiative within a country tends to occur at the national level and this will influence local deployment. Therefore, Figure 4 shows two additional columns, which deal with the specific SDI deployment issues and the external influences.

In Stage 1, *Early Implementation Stage,* the challenges faced by the organisation in the initial stages of implementation of the GIS. In this early stage, it is crucial for the GIS to have a champion, preferably at a high level, whose reach and influence is more significant. Whether a champion of the GIS is present in the organisation or not, the attention of management must be directed to the benefits of the GIS, ensuring more “champions” at different levels. Likewise the awareness of an SDI must be built and this can draw on national awareness campaigns.

In Stage 2, *Growth Stage*, from seeing what GIS can do for the organisation, management are eager to extract as maximum a value as possible from the GIS. From this and the fact that there is a drive to attract a critical mass of users to the GIS, it experiences a sharp increase in costs and new employees. The outcome of this is an increase in activity and business, which leads a saturation of GIS development capacity. The GIS/SDI development capacity can be enhanced by training key personnel.

An SDI, as an infrastructure, does not occur from scratch, but extends and wrestles with an ‘installed base’ or existing infrastructure. The growth phase must be sensitive to this powerful actor (the existing infrastructure) and pay attention to any emerging tensions. Implementation tactics are required to resolve or overcome these varied resistances.

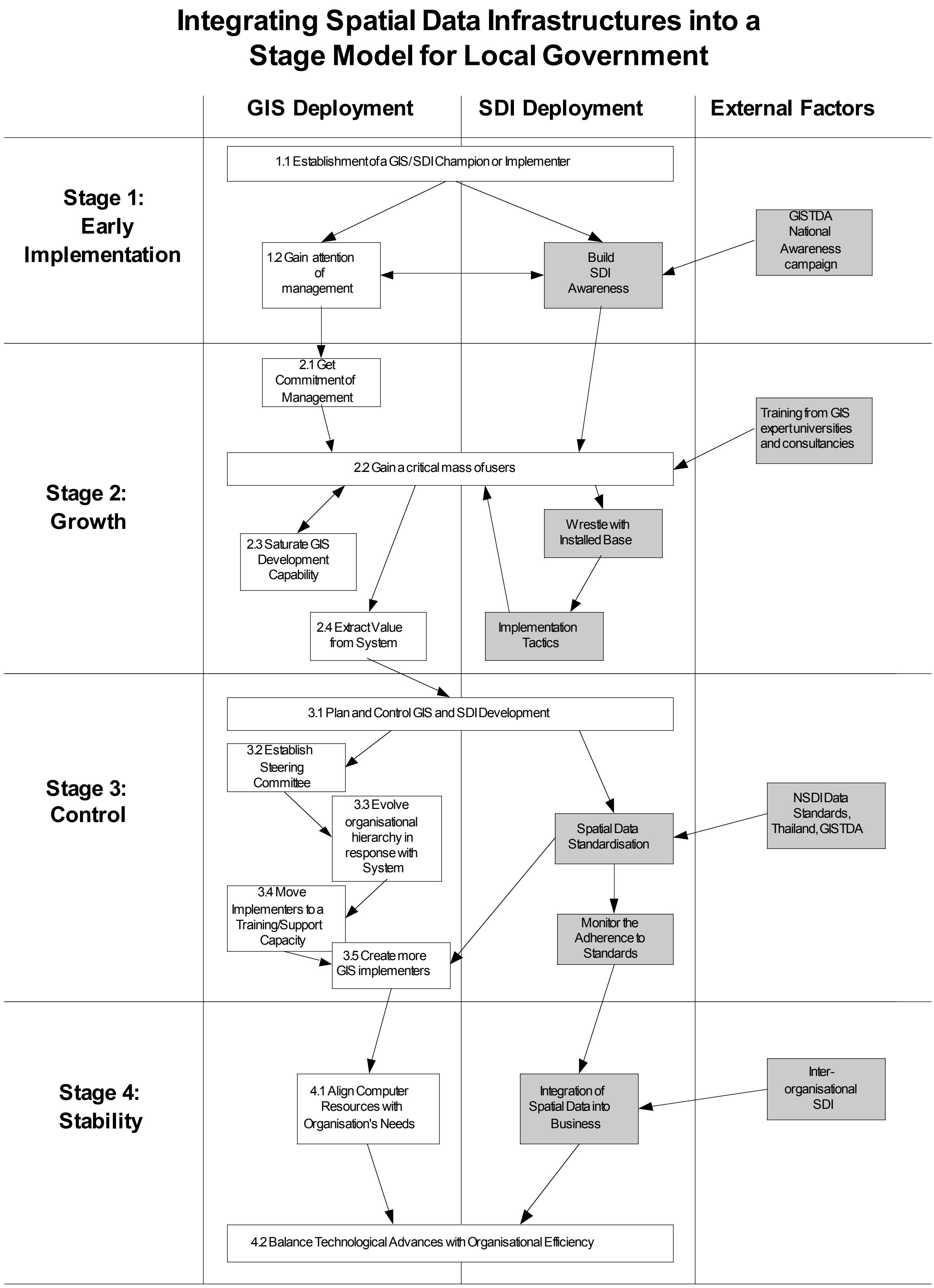



**Figure 4 - Extended GIS/SDI stage model**

(Note: Numbered boxes refer to tasks in Table 1 and new extensions are shaded.)

From this widespread growth, due to the unprecedented rise in employees, who are usually specialised and therefore more expensive, and the unchecked inefficiencies of the system, the organisation's costs spiral out of control and the organisation experiences a crisis. In Stage 3, *Control Stage*, planning and control procedures are usually enforced by a steering committee. Also, from the hiring of specialised employees or Systems Analysts, functional departments evolve and new hierarchies emerge. At this stage, implementers move to a training and support role, from which further implementers are produced. Spatial data standardisation is a key aspect of an SDI and these standards are typically defined at the national level. It is imperative that adherence to spatial data standards is monitored, ensuring high data quality.

In Stage 4, *Stability,* the organisation seeks to align the GIS with the organisation's needs. There a number of reasons for this. The moving of Systems Analysts to various functional departments provides the first GIS cross-departmental link. The increase in activity and "early wins" makes the organisation realise that the co-ordination of the GIS function across various departments will bring with it exponential benefits. Building on the planning and control introduced in Stage 4 and the communication taking place between hitherto-diverse departments, the firm reaches a period of stability, whereby growth in employee recruitment and new technology is balanced with efficiency and is evenly-managed.

Infrastructure is seamlessly reusable and is only visible through its use patterns, as it cannot be deconstructed from its use. For example, spatial data that is separated from a planning application ceases to be infrastructural and is therefore redundant. In the stability phase the spatial data must become embedded within multiple applications and in doing so it becomes an infrastructure. This becomes complex as many spatial oriented government activities span multiple local authorities, so these inter-organisational processes become an external factor.

## 5. Conclusion

GIS has been used extensively within local government and the SDI initiative, by their nature add complexity to the deployment issue. Many countries have undertaken SDI initiatives, which tend to be central and national in focus. The main motivation for this paper centres on the lack of clear guidelines for adoption of GIS and SDI at a local level. Particularly, as GIS is widely adopted in Government and within local authorities already. There is a clear interplay between GIS and SDI, so having distinguished between these; the paper highlights key characteristics that require different deployment considerations. The stage model literature was reviewed and the assimilation is presented as a basis for an extended SDI deployment model. This assimilation clearly indicates that GIS stage models exist, but these do not necessarily imply that SDI deployment will follow in the same manner. This paper makes a contribution by providing a prescribed road map that aids in the deployment of GIS and SDI within local government. It should also be useful to local authorities, who currently have limited GIS technology utilisation.

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