# Informated asphalt: the impact of information technology on urban traffic management

## (O asfalto informatizado: o impacto da tecnologia da informação na administração do tráfego urbano)

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**Abstract**

This paper considers changes in the nature of traffic management brought about by the introduction of different technologies, mostly geographic information systems (GIS). Traffic management has changed significantly since it was born about a century ago. The invention of automatic traffic lights prompted the devaluation of action-centred skills needed to manage traffic. This process was further advanced with the introduction of geographic information systems and the consequent virtualization of the work environment. In order to analyze those transformations, the paper reviews Zuboff's work (1988) twenty years after its publication. It argues that GIS have great potential not only to automate work activities but also to informate the organisation, providing a fresh view of its own reality. According to her, in order to use the information capability of GIS, the worker needs intellective skills. Besides, the organization has to provide a favourable context to explore this capability. Another consequence of the introduction of GIS is the appearance of a new form of control by surveillance: Panopticon information. Even though Zuboff's ideas about the two faces of Information Technology and Panopticon provide an insightful framework to analyse changes in the nature of work, her assumptions about the rational use of information in the decision-making process may not always occur in reality. The case study at hand and research on the actual use of information in organizations contrast with Zuboff's suggestion that IT leads to a strictly rational use of information.

**Key words**: GIS: Changes in the nature of work; Information; Urban traffic management; Intelligent transportation systems; Panopticon.

During the second half of the 20th century, technology triggered profound transformations in many work activities. Urban traffic management was not an exception. In that context, the main technology that brought about changes was Geographic Information Systems (GIS): the convergence of database technology with geo-referenced information such as the digital representation of city boundaries, roads and traffic lights, offering the possibility to relate geographic data with factual information such as the census and urban traffic data (BERNHARDSEN, 2002).

Different authors have considered the implications of the introduction of GIS at organizational, governmental or social levels (PICKLES, 1995; SAHAY; WALSHAM, 1996; WALSHAM; SAHAY, 1999; BORGES; SAHAY, 2000; HAQUE, 2001; PURI, 2007; RAJÃO; HAYES, 2007). Other studies, for example, have looked at the future and speculated about the impact that technologies such as 3D maps and ubiquitous computing may have on the future for GIS-mediated work activities (OPENSHAW; FISCHER, 1995; ARMSTRONG, 1997).

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However, when it comes to transformation in the nature of work already triggered by GIS, it appears that the literature is not abundant. This paper attempts to address this underdeveloped area in the literature by analyzing changes brought about by the introduction of GIS into urban traffic management in a major Italian city.

The current literature on information systems had successfully applied various broad social theories to understand the impact of specific applications of information technology (IT) on organizations. Barrett and his colleagues, for example, applied Gidden's theoretical concepts to shed light upon social transformations triggered by the introduction of GIS application to forestry management in India and in the London financial sector (BARRETT; WALSHAM, 1999; BARRETT; SAHAY *et al*., 2001). Following a similar line, Avgerou (2000) uses institutional theory to analyze the use of IT into an oil company in Mexico.

In order to understand the human and organizational aspect of the changes triggered by GIS, this study looks further back in the literature and reappraises Shoshana Zuboff's work. Temporally, it is possible to divide her work in three different phases. During the first phase, Zuboff (1985; 1988; 1991) presented her groundbreaking theory regarding the dual face of information technology, a result of her Ph.D. at Harvard University and her work field as a consultant of companies that have introduced IT to their organizational context. Later on, her research proposed the death of authoritative hierarchy as one of the main requirements to take full advantage of IT and enter the "Information economy" (a topic already mentioned in her earlier phase), and introduced the concept of "divisions of love" to explain how organizations value employees according to their role, and the negative consequences of this phenomenon (1995; 1996). Finally, in a book written in collaboration with a top manager, Zuboff moved away from an IT-centric perspective and argued for the creation of a new "*support economy*, based on the principles of *distributed capitalism*", were consumers/individuals, and not only corporations, own and control the sources of value (ZUBOFF; MAXMIN, 2002, p. 13).

More specifically, this paper focuses on Zuboff's most cited work, entitled "In the Age of the Smart Machine" (1988), as its main source of inspiration. This decision was based on three reasons. First, the year 2008 commemorates twenty years of the publication of that book. Second, despite its "old age" in a fast moving field, "In the Age of the Smart Machine" is still able to influence current research (see e.g. CIBORRA, 2006; WILLCOCKS, 2006; KOCH, 2007). And, last but not least, the concepts proposed by Zuboff in the book (as will be argued in the following sections) have at the same time simplicity and explicative power to describe IT-induced change in organizations. After discussing Zuboff's ideas in the context of the study at hand, this paper endeavors to point out some limitations of her work, and considers other authors in search for insights that might help understand the impact of GIS on traffic management.

The adopted research methodology to develop the case study that provides the empirical component of this paper is proposed by the interpretive tradition in information systems (ORLIKOWSKI; BAROUDI, 1991; WALSHAM, 1993). Data came from two sources. First, the author carried out semi-structured interviews (RUBIN; RUBIN, 2005), during the second semester of 2006, with the chief traffic engineer of a governmental body responsible for traffic and environmental management in a major Italian city, a lecturer in city planning at an Italian university, and the secretary for urban traffic of a city near Milan. Second, the author drew upon personal data collected while working between 2005 and 2006 as an IT consultant for an agency connected to the Urban Traffic Department of a major city in northern Italy.

The remaining of the paper is organized as follows. The first part describes how different technologies, including GIS, have changed traffic management work practices by providing a short historical background of the introduction of GIS as well as other technology-led changes. It then presents a brief review of Zuboff's theory regarding the two faces of Intelligent Technology and attempts to apply her theory to our context. The second part argues that the deployment of IT informating capability enabled the creation of Panopticon information, a new disciplinary mechanism that has changed control techniques in the traffic management context. The last part highlights some aspects of the urban traffic management context where Zuboff's theory is not able to give a full answer to the problem at hand, and endeavors to formulate a critique of her work, pointing out some alternative perspectives.

**The dual face of information technology**

Traffic management has undergone significant changes in its short lifetime. In the early 20$^{th}$ century, urban traffic management was a physical and located activity. In order to manage the traffic at the heaviest crossroads, police officers had no alternative but to place themselves in the middle of the traffic, waiving their arms and blowing a whistle to communicate directly with the drivers. The officers also had to learn intuitively from their experience motion laws governing the traffic, and make quick and autonomous decisions regarding timing to allow the flow in each direction in order to maximize the throughput of vehicles and avoid traffic jams. Those activities require a series of abilities that Zuboff calls action-centered skills. More generally, those skills are characterized by being action-dependent (manifested and learned through action), sentient (dependent on the senses of the body), context-dependent (reliant on clues coming from the environment) and personal (linked with each individual's experience) (ZUBOFF, 1988).

Zuboff argues that some action-centered skills can be embedded into technology. The skills and tacit knowledge behind those actions can be partially translated into clearly defined

rules and embedded into an automated machine during a process that can also be seen as the conversion from tacit to explicit knowledge (ZUBOFF, 1988; NONAKA; TAKEUCHI, 1995). The invention of the automatic semaphore (or traffic lights) is the result of embedding into a machine part of the traffic officer's action-centered skills, since the intellective skill concerning the time length allowed for the traffic to flow in each direction is inscribed within the semaphore clock.

Similarly, GIS and centralized traffic light systems represented another step towards the automation of traffic management. While in the past operators had to work in direct contact with every individual semaphore in its respective physical location in order to set its internal clock, with GIS and centralized traffic light systems operators can perform the same activity by manipulating a series of symbols on the computer screen, with immediate effects on the roads. As a consequence, the worker's engagement with living reality on the streets is replaced by the cold interaction with virtual reality in the computer.

Zuboff (1988) describes the embedding of action-centered skills in IT, the *automating* face of information technology. However, automation is not an exclusive feature of IT. During the last thousand years, humanity has developed different technologies to amplify and sometimes even replace the human body: from a stone axe that replaces the fist, to an airplane that replaces the legs while moving from one site to another. Taylorism is a good example of this historical trend towards work activities automation, devaluation of the importance of action-centered skills, deskilling, replacement of the human body and improved control over work activities (LITTLER, 1978).

However, Zuboff (1988) suggests that the real transformative potential of IT goes well beyond its automating "face". It lies in its capacity to generate information regarding automated work activities. The *informating* face of IT provides a new perspective about the organization's own processes. By having these informating "glasses" to look at the organization, managers and workers alike are able to innovate by improving their understanding of their everyday work activities.

The informating capability of IT can also yield immense benefits to traffic management. Before the introduction of GIS, gathering information about the traffic was slow and costly. Counting vehicles was done manually and it was impossible to have a precise idea of the traffic dynamics in the entire city at the same time. With GIS and the use of traffic sensors, on the other hand, it is possible to have both real-time and historical data concerning the traffic at different parts of the city. This new vision of the dynamics underling the flow of vehicles in the city opens a series of opportunities to optimize road usage by creating integrated traffic management plans that synchronize the semaphores of the entire city according to data gathered by the sensors.

Moreover, by looking at the data, it is finally possible to understand whether applied plans have had the desired effect or not by comparing the actual traffic flows before and after the implementation of a new plan (TANIGUCHI, 2001; DOCKRAY; ROWELL *et al.*, 2005; RAJÃO, 2006).

Unfortunately, the presence of this new flood of data is not enough to unleash the benefits promised by the informating face. In order to take advantage of radical changes in the nature of work brought about by IT, the employee and the organization have to solve a paradox that emerged with the arrival of this new technology. Zuboff points out that, on the one hand, IT deskills the worker by embedding his action-centered skills into a machine, but on the other hand, it requires more intellective skills in order to fulfill its informating potential. Intellective skills combine the capabilities of abstract thinking, procedural reasoning and explicit inference and "is the base upon which data is translated into meaningful information, and finally into knowledge" (ZUBOFF, 1988).

Intellective skills are significantly different from action-centered skills dominant in the past. As discussed above, workers use their action-centered skills while fully immersed in the real and concrete environment where the object of their work takes place, as in the example of the police officer at the centre of the crossroads. Cues coming from the environment are instinctively analyzed and decisions are made mainly in an instinctive fashion. However, when workers are interacting with a cold and abstract interface that represents the reality of their work, Zuboff (1988) argues that intellective skills are essential. In this new work context, the worker is expected to analyze all available and relevant information, and to make rational decisions based on the formal knowledge of the underlying phenomenon (e.g. urban traffic dynamics).

Consequently, because of this shift in the work nature and skills requirements, GIS operators cannot just be trained to use the system in an automatic and superficial manner. They must undertake training and formal education in order to understand the underlying phenomenon (city traffic) and the logic behind the GIS application itself. It seems, however, that lecturers in the area are already aware of this issue. Quoting a lecture of a city planning and expert in GIS:

> In order to work with GIS effectively the professional must have a double view, being a city planner with deep knowledge of the logic behind the geographic information system. The domain knowledge in city planning is necessary to conceptualize the real system, while the understanding of the logics behind of the GIS enables the professional to relate the data presented by the GIS and the real system building a holistic view of the current situation in the real world.

Zuboff (1988) also points out that the working environment must have certain characteristics to allow the delivery of the informating potential. Thus, there is a close relationship between the organizational context and the impact that information technology has

on the firm. First of all, the firm's strategy must recognize the importance the informating capability of IT, and design information systems aiming at exploring that potential. Second, there must be a structure that allows the development of intellective skills and gives space for employees to come with new ideas drawn from the information available through the system. Last, at national level, the culture and relations between institutions influence the release of the informating capability of IT. Therefore, they have to be taken into account while designing and deploying new information systems of GIS (WALSHAM; SAHAY, 1999).

Furthermore, information technology changes the location of knowledge inside the organization. In contrast to the Taylorist type of organizations, where only the management safeguarded vital knowledge (ZUBOFF, 1988), in fully informated companies the employees have a much broader perspective of the information regarding work activities. Consequently, the informated organization can have a much flatter hierarchy, thereby rendering middle management superfluous. This new kind of organization also needs common objectives or a "score", using Drucker's metaphor, that are put into practice by every single employee. Managers must be aware of this shift and use it as an opportunity instead of regarding it as a threat and forcing the maintenance of old paradigms (DRUCKER, 1988).

Concluding, it is clear that the use of GIS in urban traffic management offers great opportunities to "informate the roads", leading to the improvement of city traffic and, as a consequence, to less pollution and better life quality for the local population. However, the obstacles that have to be surpassed in order to take advantage of the informating face of IT pose challenges as great as benefits.

**Work control**

The use of IT in urban traffic management implies not only changes in the work nature and skills requirements, but also changes in work control. When traffic management was done directly on the streets, with police officers using their bodies and senses, the only way to understand if they were doing their work properly was through direct supervision by someone else with similar skills. Since the introduction of automatic traffic lights, centralized semaphore systems, and, more recently, GIS, traffic management activities have become much more open to control. Information technology eliminates the need for the "inspector" and the person under surveillance to be at the same place at the same time. Now, from anywhere at anytime, curious eyes can look at the digital traces of previously performed operations and identify human errors in them. Zuboff (1988), drawing on Foucault, calls this new mode of control *information Panopticon*.

Foucault was inspired by the work of the English philosopher Jeremy Bentham. In the end of the 18th century, Bentham wrote a series of letters proposing a building design promising "a new mode of obtaining power of mind over mind" (BENTHAM, 1995). He called this creation Panopticon: the combination of the Greek words "παν" and "οπτική", meaning respectively "everything" and "view". The Panopticon is a prison with a circular plant, with the prisoners' cells occupying the circumference. The cells have large windows to allow the penetration of the sunlight, exposing every corner of the room. At the center of the building, there is a lodge from where the inspector is able to see all cells in their entirety, while the prisoners are not able to see inside the lodge due to a backlight effect (FOUCAULT, 1977).

Bentham's mechanism to impose discipline is based on the fact that, inside the Panopticon, the controlled subject is always exposed and never actually knows if he is being inspected at a certain moment or not, so he always acts as if he were under scrutiny to avoid being punished. In this context it is obvious that "visibility is a trap" (FOULCAULT, 1977, p. 200). Zuboff (1988) noticed that the informating capacity of IT not only makes transparent the work activities of the organization, but also renders visible its employees' behavior by recording the actions performed through the system. This feature of information systems "can provide the computer-age version of universal transparency with a degree of illumination that would have exceeded even Bentham's most outlandish fantasies". As a result, "such systems can become information Panopticons" (ZUBOFF, 1988, p. 322). Under the eyes of the information Panopticon, as its brick-and-mortar predecessor, workers always act considering that someone else could observe their behavior. Doing so, they also anticipate the inspector's judgment and consequently avoid acting in a way that could shed a negative light upon themselves.

The information Panopticon can be found in the GIS for urban traffic management at different layers, forming an interesting relational loop between the observer and the observed. First, we have operators observing drivers using different types of sensors connected to the GIS systems, to identify when they do not respect the law. Second, supervisors and politicians can observe the operators' actions in the system and evaluate if they are doing their job properly. The last link of the panoptical chain is far less obvious. Smog has been one of the main public issues in major Italian cities during the last decade. Since urban traffic is regarded as one of the biggest producers of air pollution, urban traffic management is a source of major political pressure. The data produced by the sensors connected to the GIS provide a good source of information regarding the effectiveness of the politician's decisions. In this context, the informating property brings us back to the beginning of the chain by enabling voters (drivers) to inspect the politicians' actions. A lecturer of city planning at an Italian university offers us some evidence that politicians are well aware of the panoptical property of GIS:

> In the beginning of the ’90s many people argued that GIS would be a complete failure in Italy because it offered too much transparency and the politicians don’t like it. Even though as the years passed this claim was proven false, I believe that this concern is a source of adoption resistance. This may help to explain why even today less than a half of the local authorities have adopted some kind of GIS to manage their territory.

So far, Zuboff’s theory of the dual face of IT has been able to offer us some insights over how the introduction of GIS has changed urban traffic management practices. Her theory even anticipated the Panoptican proprieties of this new technology noticed by the interviewee above. However, getting a closer look at how people actually use information poses a new set of questions.

**Beyond Zuboff**

> Before the introduction of advanced information systems, city planners relied more on brainpower to carry out their tasks. Nowadays, with new tools and techniques to support their job, they tend to rely too much on the software without assessing the deployment [of plans] to actual situations, therefore not checking the effectiveness of decisions undertaken through the analysis of data gathered on the field.

This declaration of the director of the transportation department in a city near Milan contrasts directly with some of Zuboff’s ideas discussed above. Since city planners (the target of the critique above) have sound engineering degrees, it is difficult to believe those graduate professionals do not process the intellective skills necessary to carry out the task. However, instead of becoming more rational and applying intellective skills to informate themselves with data coming from the new GIS anticipated by Zuboff (1988), city planners in their decision making seem to have become less rational, not more.

Zuboff’s (1988) explanation of the processes behind the informating capability of IT, the argument about the necessity of intellective skills and the use of information in decision making, has many similarities with the Normative Decision Theory (HANSSON, 1994) and Cerebral Rationality (LANGLEY; MINTZBERG *et al.*, 1995). Even if the rational use of information for decision making proposed by those theories is very straight-forward and attractive, they are not very useful to understand the phenomena detected above. Therefore, there are reasons to believe that the “computer-like” rational use of information in decision-making, where data are coldly analyzed in a systematic way, may not always represent reality.

At this point, it is useful to set aside Zuboff’s theory and call to our assistance other authors who offer an explanation for this apparently irrational use of information. Dreyfus and Dreyfus (1986) argue that non-rational (or instinctive) use of information based on experience is not only a common reality but also desirable. Their research proposes that strict logic reasoning

leads only to limited levels of expertise, and that what differentiates an expert from a novice is the former's capacity to make fast decisions based on his or her intuition, while the latter is bound to a pure rational rule-based process. Introna (1997), on the other hand, suggests that pure rational decision making is not found in reality because it is not feasible. He points out that the decision maker is not able to analyze rationally the information as a neutral '*super partes*' because he is personally involved in the organization that is producing the information, therefore, his or her rationality is irrevocably influenced by the context. Finally, Feldman and March (1981) offer an explanation for why organizations keep gathering vast amounts of information without using them rationally. They argue that organizations (and specially managers) add a high symbolic importance to information, since it helps them to ensure their *status quo* and provides "a ritualistic assurance that appropriate attitudes about decision making exist" (178).

Even though decision making is out of the scope of this essay, this debate is useful to highlight that the relation between IT, skills, information and decision making may be more complex than initially anticipated by Zuboff. It also gives us the chance to speculate that, although new skills are needed in order to make sense of the information provided by the system, the way those skills are actually applied has not been anticipated by Zuboff, and the core decision-making process behind the use of information could have remained largely unaltered after the introduction of IT. So, even in the "Information Era", the case and the literature suggest that actors still apply their instincts to make sense of symbols on a screen.

**Conclusion**

This essay made a description of how the introduction of GIS into urban traffic management has changed the nature of work, including the skills/knowledge requirements associated with those changes, in the perspective of Shoshana Zuboff's work (1988). The paper argued that the realization of automating capability further devaluated action-centered skills (deskilling), while the needs of the informating aspect of IT generated a series of new requirements from both employees (intellective skills) and the firm as a whole (favorable organizational context). The informating of the organization also changed the way control is performed by introducing the Panopticon effect at different levels of the system.

The essay also tried to demonstrate that, even though Zuboff's theory is very useful to understand changes in urban traffic management during the last decades, it is not sheltered from critiques. It argued that the informating process and related description of intellective skills exposed by her may be seen as naïve and simplistic when analyzed in the perspective of the involved manager offered by Introna (1997), the case of symbolic use of information pointed out by Feldman and March (1981), and the instinct-based decision-making process shown by

Dreyfus and Dreyfus (1986). Therefore, the idea that the introduction of IT automatically leads to rational decision making may be unrealistic.

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**Resumo**

Este artigo trata das mudanças na natureza da gestão do tráfego urbano em razão da introdução de diversas tecnologias, principalmente dos "Geographic Information Sytems (GIS)" - sistemas geográficos de informação (SGI). A gestão do tráfego urbano mudou de forma significativa desde que surgiu há um século atrás. A introdução das luzes automatizadas de tráfego resultou na desvalorização das habilidades centradas na ação humana, necessárias para gerenciar o tráfego. Esse processo de mudança foi incrementado com a introdução de sistemas geográficos de informação e a conseqüente virtualização do ambiente de trabalho. A fim de analisar tais transformações, este artigo reavalia de forma crítica o trabalho de Zuboff (1988) vinte anos após sua publicação. Argüi-se que o SGI (ou GIS) tem grande potencial não só para automatizar as atividades de trabalho mas também para o provimento de informações à organização, eis que traz uma visão nova de sua própria realidade. Argumenta-se, ainda que, a fim de usar a capacidade de informação do SGI, o trabalhador precisa de habilidades intelectuais adequadas. Além disso, a organização tem que prover um contexto favorável para a exploração dessa capacidade. Outra conseqüência da introdução do SGI é o aparecimento de uma nova forma de controle por vigilância: o Panóptico da informação. Mesmo se as idéias de Zuboff sobre as duas faces da Tecnologia da Informação e o Panóptico proporcionem um quadro inspirador para analisar as mudanças na natureza do trabalho, seus pressupostos sobre o uso racional da informação no processo decisório pode não ocorrer na realidade. O estudo de caso realizado e a pesquisa sobre o uso real da informação em organizações contrasta com a proposta de Zuboff de que a TI nos leva a um uso estritamente racional da informação.

**Palavras-chave**: SGI; Mudanças na natureza do trabalho; Informação; Gestão do Tráfego Urbano; Sistemas Inteligentes de Transporte; Panóptico.

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