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A STUDY OF THE NATURE OF DATA USING A COMMUNICATION-BASED CONCEPTUAL FRAMEWORK OF LAND INFORMATION SYSTEMS

(updated version)

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Land Information Systems (LIS) are described as complex communication processes between collectors (e.g. land surveyors) and users of data (e.g. decision makers). This is illustrated by a conceptual framework of LIS, highlighting the many models of the reality then created. The surrogate nature of land data is emphasized with its inherent uncertainty. Remedies are defined in terms of uncertainty reduction and uncertainty absorption, the latter affecting the nature of data.

Les systèmes d'information sur le territoire (SIT) sont décrits comme étant des processus de communication entre collecteurs (ex. arpenteurs-géomètres) et utilisateurs des données (ex. preneurs de décision). Le tout est illustré par un schéma conceptuel de SIT mettant l'emphase sur les différents modèles de la réalité alors créés. La nature symbolique des données est mise en évidence ainsi que leur inhérente incertitude. Des solutions sont décrites en termes de réduction et d'absorption de l'incertitude, l'absorption affectant la nature même des données.

INTRODUCTION

Land Information Systems (LIS) consist of procedures for the systematic collecting, storing, retrieving, updating, controlling, processing and distributing of land-related data. To this point the emphasis in research and development has been on the technical and institutional aspects of LIS. Limited attention has been given to what feeds these systems: land data. This paper presents some findings of recent research about the nature of land data, that is what they are, how they are created, how they evolve, how they are transmitted, how they are distorted, and their veracity. By understanding this very nature of data, LIS can be designed to provide better information to the users, leading to better decision making.

This research relies on communication sciences, information theory and computer sciences. First, the process of communication and the triad ''data-information-knowledge'' is explained. Second, LIS is described as a communication in process with certain particularities. Third, this process is illustrated by a conceptual framework of LIS. Fourth, the complete data flow is followed from the observation of the reality to the use of the resulting data. Finally, some aspects of the nature of data and two fundamental concepts of uncertainty reduction and uncertainty absorption are presented, the latter concept affects the nature of land data.

Seeing information systems as a communication process is rather unusual, although not new [Meadow 1967; Thayer 1968]. An important aspect of LIS, cartography, has also been considered a communication process for 15 years [Ratajski 1973; Robinson and Petchenik 1976; Morrison 1976; and Keates 1982]. And, in the LIS community, this point of view has also been introduced [Wunderlich 1969; Moyer 1980; Chevallier 1981; Frank 1982; and Holmberg 1985]. Nevertheless, this research has introduced several new findings, some of which are presented in the following text.

BASIC CONCEPTS

It is generally accepted that the concept of information is tied to the idea of communication (Schramm 1971; Frandsen and Clement 1984). Both concepts, which are fundamental to LIS, are presented in the following paragraphs.

Communication

Communication has been given many definitions, numbering more than a hundred, with no one being widely accepted. This fact is perhaps best illustrated by the 126 "scientific" definitions given in *Dance and Larson's* book [1976]. For the purpose of this research, communication can be defined as "reproducing at one point either exactly or approximately a message selected at another point" [Shannon 1948 (1963)] (The phenomena is illustrated in is most simplistic form by Shannon's general model of communication (Figure 1).

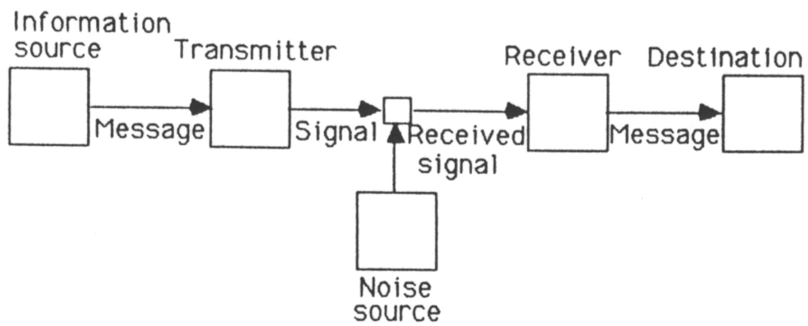

Figure 1: Shannon's general model of communication [Shannon 1948 (1963)]

A more specific description of this process is needed, one involving semantics. In the following paragraphs, the simplest communication is described: direct human communication.

First, there is the real world, assumed objective and independent of the observer, which is very complex. To make decisions about this world, abstraction is necessary. To do so, human beings selectively perceived the reality where living beings, objects, places, events or their surrogates emit or reflect different signals (light, sound, odours, etc.).

Observers pick up these signals through their sensors, that is the five senses with their physiological limitations. To expand human knowledge some of the signals are amplified or translated by technical devices.

The detected signals travel to the observer's brain to be interpreted (recognition). This consists of matching the detected signals with previously stored referents to give meaning to these signals. The observer mentally reconstructs the observed part of the reality. This cognitive image is the first model of the reality in the communication process. It is subjective since it depends not only on the reality, but also on the context and on the observer. However, it is assumed that common sense renders this cognitive model approximately correct at least within a cultural or professional group.

Afterward, the observer communicates his cognitive model. However, mental models cannot be communicated directly: physical counterparts such as sounds, drawings, and writings must be created. Using the right physical counterpart or signal to communicate the desired meaning is called encoding.

These encoded signals when put together, form a second model of the reality. They form a physical model which stems from the observer's way of perceiving the reality, not from the reality.

These transmitted signals then have two components: a content and a form [Gerbner 1956]. However, the signal itself is only the form of a message, it has no built-in content. Thus, when communicating, only one component is transmitted: the form. Nevertheless, these signals convey an intended meaning or content.

The same content may have different forms: for example, land use can be physically represented by a map or a listing of the zones with their use. Inversely, the same form can lead to different contents for different people or different contexts; fore example, the word "lot" often means different entities for the surveyor and the assessor.

Thus, a crucial characteristic of communication is the sharing of common language by the source and the receiver of a message. If they do, the chance that they attach the same meaning to the transmitted signals is relativity high.

The transmitted signals are sent through the selected channels (e.g. air, telephone cables). To be received, they must be in the detection range of the receiver. They can then simulate the receiver's sensory organs and travel to his brain.

To complete the act of communication, these signals must be decoded, that is the receiver must perform the inverse operation of the sender's encoding, but with his own referents. He must "guess", among potential meanings, the one conveyed by the received signals. This interpretation of the message symbolically sent to him allows the receiver to create his own cognitive model of the reality, the third one. This step is also context and receiver-dependent.

If the "commonness" between the sender and the receiver is high, the message will be interpreted with little distortion, the "picture in the head" of the receiver will bear a marked resemblance to that in the head of the sender [Schramm 1954].

It is only when this third model of the world, created from a physical model instead of the reality, is made that the communication process is completed. Thus, direct human communication is a cognitive-physical-cognitive modeling sequence.

This manner of reproducing a subset of the reality allows users to become informed about aspects of the world without observing everything themselves.

Information

Information also has legion if definitions. For this research, a commonly used approach as been adopted, one that is also very well suited to LIS. We understand information as (1) something that has to do with the forming or changing of the internal mental model that someone has of a piece of the world (Lat. informare: "in" meaning inside. and "formate" meaning to put into form), (thus involving a mind and a cognitive process: (2) as the commodity transferred by the communication process [McGraw-Hill *Encyclopedia of Science and Technology* 1966]; and (3) as one of the possible outcomes of a message (other ones being instruction, persuasion, and entertainment [Schramm; 1971]).

Any other meaning is considered a metaphor or too restrictive. Common examples of where the term information has been reduced are information with the requirement of novelty, of uncertainty reduction, or of effectiveness.

Without philosophical debates on this aspect, some of the premises set forth are that (1) knowledge about something often contains a mental model of it, (2) information helps us to build, verify or improve these mental models, and (3) information is built from observing surrogates of the reality, that is data. Such an ascending hierarchy of the triad date-information-knowledge has been widely used; it is sufficient and consistent enough to study the nature of land data. Each term is further explained in the following paragraphs.

The world data, a Latin word, is the plural form of datum which means “something given”. Data, in a communication process, are thus the things given to the receiver in whatever form. They are the raw material of information.

Information was previously defined. It results from the decoding and interpretation of data. Information exists only in the mind of someone, it can only be transmitted indirectly via physical symbols (data). For example, measurements written on a subdivision plan are data: to speak of information in such a case, although popular, is just a metaphor. It is when the reader interprets these written symbols that he understands what they mean and that they provide information. Without the appropriate cognitive capability of the receiver, no information is communicated.

Knowledge is built, among other things, from information. The distinctions between information and knowledge have been proposed mainly on three points: (1) that information is piecemeal, fragmented, and particular, whereas knowledge is structured, coherent and often universal; (2) that information is timely, perhaps ephemeral, whereas knowledge is of enduring significance; and (3) that information flow, whereas knowledge is stored [Machlup 1983].

A COMMUNICATION PARADIGM OF LAND INFORMATION SYSTEMS

According to the previous concepts, LIS are complex communication processes where several collectors of data (e.g. land surveyors) observe a part of the world (e.g. a property), create cognitive models of it (e.g. opinions), codify and transmit them in the form of data (e.g. plans) via an intermediary (e.g. “Service du cadastre” in Québec) to the many users (e.g. planners, assessors). After interpretation, these users create their own cognitive model of the reality, become informed, and improve their knowledge of the world, leading them to better decision making.

Here we recognize the raison d’être of LIS: reproducing at one point (the LIS users’ minds) the realities observed at another point (by data collectors). Thus a LIS achieves its goal if it helps to build, verify or improve the users’ knowledge of the world without the need for him to directly observe everything. This is the fundamental basis of the communication paradigm of LIS.

Thus, the output of a LIS is information for the user. It is not the decisions/actions made while using this information, especially as these are out of the control of the LIS. Neither is it the output of the LIS technical subsystem (e.g. maps and listings) which is used by him because communication does not exist before the receiver interprets the data. This approach shifts the actual emphasis of LIS from providing data to providing information.

A COMMUNICATION-BASED CONCEPTUAL FRAMEWORK OF LAND INFORMATION SYSTEMS

As a communication process, an LIS presents some particularities ;
• it is indirect, i.e. mediated by a "technical subsystem";
• it is n-to-m, (n = number of observers, m = number of users) usually with m > n;
• it is not interactive, providing only minimized feedbacks;
• it presents time and space delays;
• it is mostly one-way, with a main direction sender-to-receiver;
• it is structured and formal, following specific rules;
• data are purposely generated for a specific goal, but are potential for unintended goals and receivers.
Based on these particularities, we can develop a general conceptual framework of LIS (Figure 2).

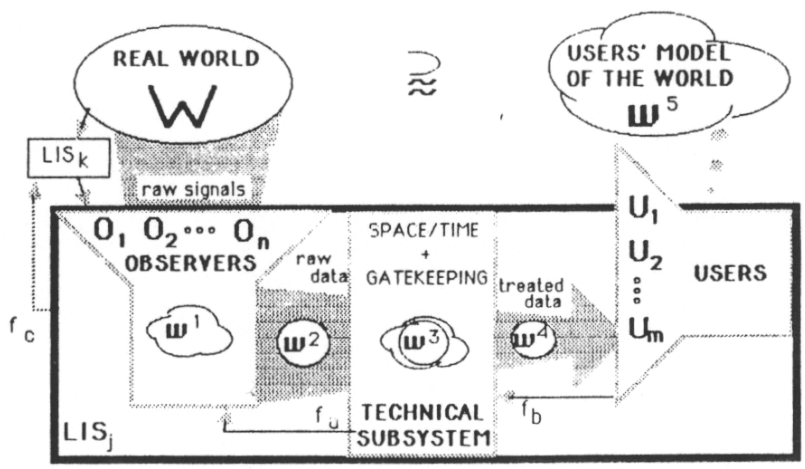

Figure 2: a general conceptual framework of LIS

This framework shows the most important steps in the general communication process taking place in a LIS. These steps, found along the grey arrow representing the data flow, are described in the following paragraphs.

The real world W is observed by n data collectors O (Observers) who, as sources of the communication process, select, estimate, abstract, and transform their observations of W's raw signals into cognitive (w^1) and ultimately into physical (w^2) models (e.g. surveyor's opinion and subdivision plans). The model w^2 provides the encoded signals, or raw data that can be used by the intermediary to which it is transmitted. This intermediary is called the "LIS technical subsystem".

This technical subsystem is the central organization of a LIS and groups men and machines (e.g. Land Court in Massachusetts and the "Service du Cadastre" in Quebec). It is the system leader controlling the communication between the observers O and the users U. It controls where, when, how and which data are received, stored, duplicated, treated, updated, retransmitted, and under which controls. It can also be designed to minimize the data treatment to he done by the users. These major functions give to the technical subsystems the role of gatekeeper in the LIS communication process.

After space and time delays, the LIS technical subsystem transmits the final data to the users, these are called treated data. Meanwhile, it has created two additional models of the reality: (1) the physical/cognitive models w^3, the physical ones being stored in the LIS data base, and (2) the physical model w^4 which is transmitted to the destination or m users U. These two models can be physically the same as w^2 (e.g. in repository LIS) or new models of W (e.g. in LIS offering data processing for external users).

The model w^4 containing the treated data is finally received and decoded by the users U. After interpretation, these data become information useful to the user's cognitive model w^5.

This is this fifth model which is used for decision making: that is, the furthest away, among all models, from the reality. It represents what U knows about W without having observed it himself (the communication paradigm of LIS). To be useful, w^5 must be a very good model of W, that is it must resemble W, and questions or functions performed on w^5 must agree with those performed on W [Minsky 1965]. This is illustrated by the symbol "≈" and is similar to the mathematical concept of homomorphism as noted by Frank [1982]. However, homomorphism in its mathematical sense is impossible to achieve in a LIS. As opposed to mathematics where exact concepts are the rule, inexact concepts prevail in the real world, and only a "relative" homomorphism can be achieved, extending the sense of that word for LIS purposes. Nevertheless, "perfect" homomorphism remains the ultimate goal of LIS.

A general characteristic of LIS, especially multi purpose LIS, is that they use data from other LIS. This is illustrated in the framework by the use of the subscript j for the system under study and by the external box LIS_k representing the other LIS.

Furthermore, the U's sometimes (1) have the choice among LIS to obtain data and (2) they may themselves observe the reality. This possibility is represented by a "user polygon" stretching out of LIS_k and looking toward LIS_k and W. The choice of the users (U's) depends upon several factors including time, money, and task requirements, as well as the commodities offered by the LIS (e.g. standards, integration, reliability, updateness, etc.). In all cases, the model obtained, w^5, is only a small subset the reality; this is represented by "$\supset$".

This whole communication process could not be effective without feedbacks: (f_a) from the technical subsystem to the O's, (f_b) from U's to the technical subsystem, and (f_c) from LIS_j to LIS_k. The whole LIS relies on these feedbacks to continuously adjust its functioning according to internal and external demands and problems. Thus, to survive, LIS must be cybernetic systems looking for an equilibrium called ''homeostasis" [Wiener 1948].

It must be specified at this point that a role in LIS communication process (source, destination, gatekeeper) is not to a specific person or equipment but instead to his functions performed by these. For example, a land surveyor can be both O and U for the same LIS at different times depending on what function he is doing (e.g. making subdivision plans vs. studying titles).

UNCERTAINTY IN LAND DATA

An LIS is a sequential building of models of the reality (Figure 3), models that are either cognitive or physical (respectively represented by clouds and circles in Figures 2 and 3). Each time a model is built, uncertainty is introduced in the LIS communication process.

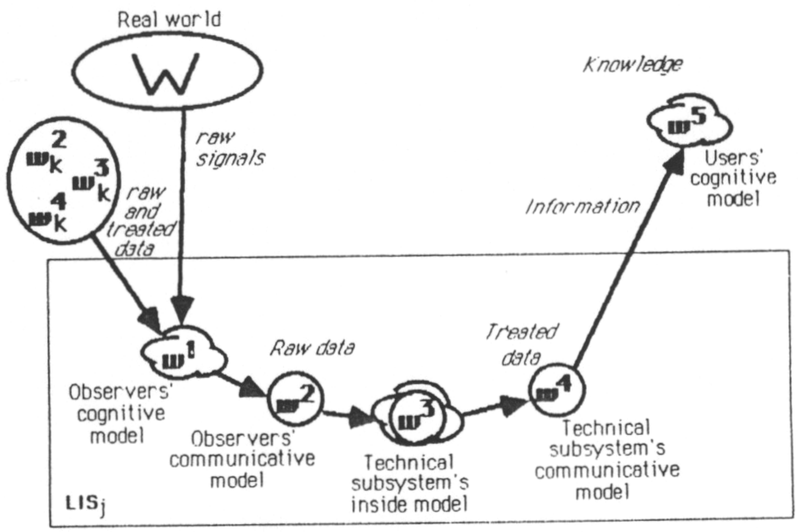

Figure 3: evolution of models in LIS

The introduced uncertainty can be related to two aspects. First, it can be related to the limitations inherent to the modelization processes involved when creating models of W or when communicating them. These intrinsic limitations are the two kinds: fuzziness in the identification or labelling of an entity, and limitations in the measurement of the properties of these entities (see Bédard [1986b] for more details).

This uncertainty can also be related to the participants in the LIS communication process, that is the observers O's, and the users U's. Humans, as information processors, have limited capabilities and they introduce subjectivity in the data (see Bédard [1986] for more details). It is commonly accepted that even in the best conditions, a same reality will not be modeled the same way by different persons, or by the same person in different times and contexts. Communication scientists talk about the particularity of everyone's "frame of reference", meaning someone's history, experience, learning, needs, aspirations, beliefs, values, and personality. This also includes someone's group norms: cultural, professional, and familial.

Uncertainties stemming from these two categories of causes are unavoidable. Consequently, an LIS cannot deliver perfect information. At best, LIS data bases can only be workable approximations of the real world W.

These sources of uncertainty directly affect the data disseminated by any LIS (w^4). Thus, there is an inherent uncertainty in land data that cannot be avoided. It can be about the identification, the location in space and time, and the description of the observed realities. This gives rise to four orders of uncertainty (see Bédard [I986b] for more details):

- First order (conceptual uncertainty): refers to the fuzziness in the identification of an observed reality (e.g. is it or is it not an entity? It is entity type A or B?).

- Second order (descriptive uncertainty): refers to the vagueness in the attribute values of an observed reality (e.g. imprecision in quantitative values, unclear qualitative values).

- Third order (locational uncertainty): refers to the vagueness in location in space and time of an observed reality (e.g. error ellipses in geodesy).

- Fourth order (meta-uncertainty): refers to the degree to which the preceding uncertainties are known (e.g. absolute error ellipses with a probability of 39.3 percent).

These four orders of uncertainty combine with each other to generate uncertain information about the real world (W). The first order of uncertainty, conceptual uncertainty, influences indirectly the veracity of the data. Only two orders apply directly to land data: either the second order, descriptive uncertainty, or the third order, locational uncertainty, depending upon the type of data, and plus the fourth order, meta-uncertainty.

UNCERTAINTY REDUCTION AND UNCERTAINTY ABSORPTION

There is an inherent uncertainty in land data that cannot be avoided. There are three choices: (1) do nothing, (2) reduce this uncertainty, and (3) partially or completely absorb the remaining uncertainty. The choice among these alternatives is institutional and is to be done within each jurisdiction.

Uncertainty reduction takes place when modelization rules (what to observe and how) and communication rules (use clear standard language) are established either (1) to decrease the fuzziness associated with the identification of a spatial entity or (2) to insure precision in the description and location in space and time of this spatial entity.

This can be done by appropriate technical, procedural organizational and legal requirements such as geodetic tying of surveys, use of adjustments for measurements, good professional training, high precision standards, mandatory marking of property corners, use of standard symbols, inclusion of lineage in digital maps, mandatory registration of all the rights to the land, etc. Such methods increase the likelihood that the several models of W built in the LIS communication process will correspond more closely to W, the real world.

Any LIS reduces to a certain degree the uncertainty inherent in land data. However, this is limited by fundamental concepts as well as practical and economic conditions. Although we can reduce the uncertainty inherent in land data, we cannot eliminate all of it. Thus, there remains, in the LIS communication process, someone who absorbs, in whole or in part, the remaining uncertainty.

Uncertainty absorption takes place when a model maker guarantees his model of the reality and compensates the users damaged by poor data. Uncertainty absorption also takes place when nonguaranteed models are utilized or when the compensation for use of guaranteed models is incomplete. Here, the user and not the provider of data absorbs the uncertainty. In fact, the level of uncertainty absorption is defined as the level of (monetary) risk in providing or using data. When errors in data cause damage in users, the ones who pay for these damages are the ones who absorb the uncertainty.

Uncertainty absorption is very different from uncertainty reduction. In the latter case, the uncertainty is literally reduced (i.e. requiring precision of 0.1’ instead of 1’, asking for the opinion of two or three land surveyors instead of only one). In the former case however, there is someone who guarantees the data as the “truth” and who is willing to take the accompanying risk (e.g. guaranteed titles).

Only the absorption performed by the gatekeeper applies to all the participants and influences the nature of land data. Where this happens, the gatekeeper guaranties the power and means to impose a specific model of the world. Thus, when the gatekeeper guarantees the disseminated data, or model w^4, they become the “official” view of W, a kind of “artificial truth” binding every participant in LIS. Although these models do not necessarily represent exactly the reality, they represent the “official” model of W and they are guaranteed.

This official status becomes part of the nature of land data, shifting it from simple approximate surrogates to “artificial truth” where priority is given to the model instead of to the reality. Then, the reality becomes “defined” according to a model (e.g. priority of the cadastre over the occupancy in some registration systems). Such an alternative almost eliminates the uncertainty inherent in the original nature of data, it really absorbs it, and the decision maker can better rely on such data. User of these must and can rely on them.

Examples of uncertainty absorption are the guarantee of titles and the guarantee of boundaries in registration systems with indemnity funds (e.g. Massachusetts).

The higher the uncertainty reduction, the lower the uncertainty absorption needed; and higher the absorption by the technical subsystem, the more secure the user. The right balance between uncertainty reduction and absorption for an LIS is a cultural, political, and economic matter.

It is interesting to note at this point that most of the ways to reduce uncertainty are technical, while most of the ways to absorb the remaining uncertainty are institutional.

ABOUT THE NATURE OF LAND DATA

We now have the necessary elements to analyse the nature of land data. In Bédard [1986b], this analysis consists of 27 axioms. In this paper, only a summary of the most important aspects are presented.

What Land Data are, how they are Created, how they Evolve, and how they are Transmitted

Land data are physical and formal symbolic surrogates created by humans to communicate information about the description and location of land-related realities. Land data are units of content and form; they are basically physical forms (e.g. written symbols) without any intrinsic content, but they convey an intended content according to formal rules. This content must be interpreted by the U’s for communication to take place. Thus, land data are the physical coded signals, or symbols of the LIS communication process. They can be stored, duplicated, changed, modified, transported over time and space, and disseminated.

How Land Data are Distorted and their Veracity

Land data provide only a reduced level of cues, they do not call forth all the responses that the observed objects themselves call forth. Land data are goal, context, and observer-dependent; thus, they are more or less objective representations of W. Using data creates a loss of details because they are discrete while the world is a continuum. Furthermore, it was said that land data are affected by up to three orders of uncertainty which combine with each other to increase the total uncertainty for the information. Thus, land data are only estimations and have an inherent uncertainty that cannot be avoided.

However, this inherent uncertainty can be reduced and absorbed. This results in two kinds of data:

• *Second class land data:* these are the typical data found in LIS, they have an inherent uncertainty which remains because it has not been absorbed. They remain approximate surrogates that lie on a spectrum going from "vague" on one end (data with a lot of uncertainty remaining) to ''precise'' on the other end (little uncertainty remains).

• *First class land data:* this type of land data is rare, these are the data for which the uncertainty has been absorbed by the LIS gatekeeper. These land data are the "official model" binding every participant in the LIS. The original nature of these land data has been changed to "artificial truth'' and no uncertainty remains for them.

Precise land data can then be considered as very good approximations; and, much technical effort has been spent to improve precision. But, only the "first class" land data can be considered as having a total veracity, and this can only be done using institutional means.

CONCLUSION

Society is increasingly being built around "centers of information". All these new institutions have not completely replaced interpersonal communication since it is still possible for a data receiver to directly communicate with the source of data. Nevertheless, for reasons of efficiency, centers of information such as LIS have supplemented and extended the interpersonal communication, especially through time and space.

If sciences such as informatics, geodesy, and mapping contribute to solving many of the technical aspects of LIS, we must then turn to sciences such as human communication and information theory to design better LIS. This also helps to better understand the nature of land data, a fundamental step in analyzing the veracity of data bases in LIS.

Based on these sciences, this paper introduces innovative ways to analyze Land Information Systems:

• The recognition of the "communication paradigm of land Information Systems".
• The building of a new, simple and coherent conceptual framework of LIS. This framework was developed for a specific goal, but it provides a systematic approach to LIS which, when combined with other frameworks, should help to better understand LIS.
• The identification of the LIS technical subsystem as the LIS gatekeeper.
• The identification of four functions not generally depicted for LIS: (1) the establishment and control of modelization rules, (2) the establishment and control of communication rules, (3) uncertainty reduction, and (4) uncertainty absorption.
• The identification of four orders of uncertainty: conceptual, descriptive, locational and meta-uncertainty.
• The differentiation between uncertainty reduction and uncertainty absorption.

In cartography, the advent of the communication point of view has been considered a significant contribution and has given birth to what is known today as the "communication paradigm of cartography". Its importance prompted the International Cartographic Association to create Commission IV which deals with cartographic communication.

Improvements in LIS studies can also come from the communication paradigm of LIS. We can see "the field of LIS'' as the study of the communication of land-related information.

This point of view has already provided innovative ways to analyze LIS as well as provide a foundation for further research, either to work on the paradigm itself or to analyze actual topics in new ways. Examples are: comparing land conveyancing systems [Bédard 1986b], differentiating LIS and GIS, analyzing precision standards, improving homophormism in LIS, adapting professional training, studying standards for data exchange, analyzing and comparing the distribution of uncertainty reduction and absorption for certain jurisdictions, and simulating the effects of technical and/or institutional actions in a LIS.

Finally, as stated by Morrisson [1976], "in order to establish a unified body of theory, scientists in a field must agree on a fundamental paradigm"; this paper proposes a communication paradigm for Land Information Systems.

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