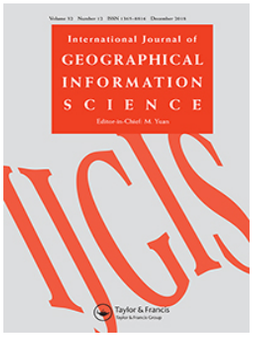

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Andrew U. Frank's impact on research in land administration

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ABSTRACT

Andrew U. Frank retired in October 2016 after a scientific career of 38 years with positions in Switzerland, Maine and Austria. One of the main applications that he constantly referred to and that he analysed in detail was land administration. This review article tries to give an overview of Frank's work in the context of land administration and how he influenced the approach to land administration research. He organized his work mainly in four pillars: technical, legal, organizational and economical aspects. Each of them is discussed in the paper and the influence on international cooperation is shown.

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1. Introduction

In his 2006 keynote on land change modelling, Gilberto Camara compared the role of Andrew U. Frank in geographic information science (GIS) with that of Johannes Kepler for the model of physical reality (Camara 2006). Frank analysed systems and relations using formal methods like algebraic modelling. An example that he used throughout his career is the cadastre, which is an essential part of land administration. This is not surprising, given his background in civil engineering and surveying. His first paper in 1979 dealt with the realization of a Land Information System (LIS) in Switzerland (Chevallier and Frank 1979), a term used at that time for digital cadastres applying GIS technology. Already in this paper, technical, legal and organizational aspects were discussed and it became obvious that these questions could not be treated independently. Fifteen years later, he mentioned economic aspects as the fourth important topic in LIS: 'Many applications are economically not attractive, if the required data have to be captured and updated by the users themselves'[1] (Frank 1994, translated by the author).

This is in line with the standard definition that land administration 'supports the management of real property' (Dale and McLaughlin 1999, p. 10). Although the term land administration was coined in the 1990s, the demand ranges back to ancient times (compare Kain and Baigent 1992, p. 1). The need for more accurate maps and a solid basis for land-related taxes initiated new survey initiatives in the sixteenth and seventeenth century, e.g. in the Netherlands or Sweden (Kain and Baigent 1992, p. 13ff; 51ff). Technological developments pushed the resulting systems further in the eighteenth and nineteenth century when the political leaders were looking for a stable source of income

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to finance the wars in Europe and tried to restrict the social differences between nobility and farmers (Twaroch *et al*. 2016). In many European countries, this development together with the codification of national legislation in the nineteenth century led to land administration systems consisting of a technical component defining the geometry, often referred to as cadastre, a legal component defining rights, responsibilities and restrictions, the land register and additional components if necessary, e.g. for property valuation or yield assessment. The technical development after the Second World War enabled the cadastral authorities to use digital technologies to maintain their data. Austria is used as an example for the work done at that time, but the situation was similar in other countries. The digital age in the Austrian cadastre started in 1957 by storing parcel data on punch cards and using computers for the calculation of coordinates (Zachhuber 1973, Mansberger *et al*. 2016). Later, databases were used to store coordinates of control points (Hörmannsdorfer 1979). In 1978, the creation of a national parcel database was started as a project of the Ministry of Building and Technology (responsible for the cadastre) and the Ministry of Justice (responsible for the land register) following a successful test phase (Kloiber 1979). This project was planned to be finished around 1990. This was a sound technical development. However, the only systematic vision for a future development was the idea of a multipurpose cadastre documenting underground supply lines in addition to the parcel boundaries (Höflinger 1978). This was the situation when Frank finished his master thesis in Zurich in 1978.

The goal of this paper is to analyse how Frank's research work influenced (and was influenced by) both the people in his group and the international community. The paper also identifies the aspects of land administration that he focused on and developed further by theoretical and applied research. His direct impact on existing systems was limited since he did not cooperate extensively with national authorities. His interaction with the research community, though, had an indirect effect.

2. Land administration

The definition of land administration by Dale and McLaughlin (1999, p. 10) has already been mentioned. It divides the functionality into the juridical, regulatory, fiscal and information management component. A more recent attempt focuses on land (use) rights: 'Land administration embraces legal rules for land use related to a certain area. As information (site, value, etc.) about such an area is essential, the tools for assessing, documenting and mapping this information are parts of land administration' (Mattsson and Mansberger 2017). By documenting land rights and their boundaries, land administration protects private property, which has been identified as a major criterion for economic development (De Soto 2000, p. 46). The connection between land value and demand for protection has been analysed and illustrated by Barnes and Griffith-Charles (2007).

The initiatives to implement land administration systems are quite old. One of the oldest endeavours to establish a land administration system based on a complete and accurate surveying and mapping was initiated by Prince Eugene of Savoy during his time as governor general between 1707 and 1715. The result was the Cadastre Milanese or Catasto Teresiano. It was intended as an objective basis for land taxation, which was achieved by surveying, mapping and yield assessment. In the nineteenth and twentieth

century, systems to document ownership and other land rights were implemented in many European countries to complement the technically oriented cadastral systems.

Land administration was in constant state of change due to the improving technology and changing legal settings. The original technologies of measurement included chain measures for distance measurement and plane tables for local mapping. Electronic distance measurement became possible in the second half of the twentieth century leading to different measurement strategies. Later, global navigation satellite systems revolutionized positioning and the online availability of high-resolution imagery enabled approximate surveying by Internet. Additionally, the political system in many countries changed, e.g. from monarchy to democracy, resulting in a different role of state and state representatives in public life. Systems like cadastre and land register had to adopt to these changes, technically and organizationally.

In the early times of GIS, the relation between GIS and LIS and their separation from other concepts like maps was unclear. Frank worked on these questions and pointed out that an LIS can be a data source for a GIS. The main difference at that time was the update rate, which was lower for a GIS than for an LIS. Today, GIS can be seen as the general concept and LIS could then be a more focused example of a GIS. In 1980, questions like the efficient storage of spatial information were still unsolved and simple tools for data manipulation and retrieval were missing (Frank 1980).

3. Research on land administration in Andrew U. Frank's group

Frank did research on land administration-related topics during his time in Switzerland, Maine and Austria. The focus changed slightly, of course, because new locations also provided new examples. His work in Switzerland concentrated on Swiss developments, although he tried to generalize to match at least central European systems. During his time in Maine, he was introduced to the different systems used in the USA and South America. Back in Europe, he finally had a closer look at the Austrian system and various other systems including the Italian, the Danish and the Swedish system. The following discussion is arranged by different aspects of land administration research. Having studied at a technical university, clearly his focus was on technical aspects in the first phase of his career. However, he never ignored legal, economic and organizational questions.

3.1. *Technical aspects*

In the first years of his research, the use of databases for LIS was one of his major research topics (Frank and Tamminen 1981, Frank 1981a, 1981b, Frank and Studemann 1983). His work on the use of database management systems (Frank 1981a) was cited by renowned experts like Max Egenhofer or Peter van Oosterom. However, he moved on to different types of questions in the early 1980s by asking the questions that could be tackled once these technical issues were solved.

One of the first new approaches was the measurement-based cadastre. The idea is simple: Surveyors perform more measurements if better quality is required. The method of adjustment computation (Gauß 1821, Ghilani 2010) then produces optimal results. It is possible to integrate old and new observations (with lower and higher quality) in a single mathematical framework. This would solve a classic problem of cadastral

processes, the fact that locally adding high-quality surveys to larger maps with lower quality does not improve maps' quality but reduces the quality of the newer results due to the fitting process. The theoretical basis was developed by Taher Buyong (Buyong and Frank 1989, Buying *et al*., 1991, Buyong and Kuhn 1992). The topic was later revisited by Hintz *et al*. (1996) and Goodchild (1999). The release of the ArcGIS® extension Survey Analyst in 2003 led to the conclusion that modern software was available to implement the concept (Joffe 2003), a claim that was later tested and significantly restricted (Navratil *et al*. 2004). The topic is still relevant as can be seen by recent citations, e.g. by Belussi and Migliorini (2012), Wilke (2015) or Berk and Ferlan (2016), because it provides a straightforward path to improve the quality of continuously updated data sets with time and avoids contradictions.

The National Center for Geographic Information and Analysis, formed in 1988 by Michael F. Goodchild, David Mark and Andrew U. Frank, began to investigate spatio-temporal analysis in 1993 (initiative 10 with the co-leaders Max Egenhofer and Reginald Golledge). In the same year, Al-Taha and Frank (1993) analysed the application of spatio-temporal analysis to cadastral systems. Damir Medak in Vienna (Medak 1997, 2001, Frank and Medak 1999) and Kathleen Hornsby in Maine (Hornsby and Egenhofer 2000) later investigated the basic concepts of time in databases but only Al-Taha (2001) made a reference to cadastral applications. Time in land administration was integrated into the Land Administration Domain Model (LADM, ISO 19152) because documentation of history requires this (Lemmen and Van Oosterom 2013). The concept is similar to that developed by Al-Taha, Medak and Hornsby but does not extend their work. More could be done and could lead to interesting insights (compare Navratil and Fogliaroni 2013).

After moving to the Technical University Vienna in 1991, Frank focused on formal modelling of the cadastral system itself. Various modelling techniques were used, e.g. object-oriented modelling (Frank 1996a, 1996b, Navratil 1998, Navratil and Frank 2004), logical modelling (Bittner 1998) and agent-based modelling (Bittner 2001). The insights from these models were then used, e.g. to analyse cadastral correctness (Bittner *et al*. 2000, Bittner and Frank 2002, Navratil et al. 2005b). This work prepared the group in Vienna to participate in international discussions, e.g. the COST (European Cooperation in Science & Technology) action G9 project discussed in Section 4.

The EU-funded ReviGIS project (1998–2004) and Frank's organization of the International Symposium on Spatial Data Quality in 2004 opened the research field of cadastral quality. The work ranges from quality requirements and assessment of quality to the determination optimal data quality. The starting point was Nick Chrisman's concept of fitness for use (Chrisman 1984), which assumes that users know their quality needs. Krek and Frank (1999a) looked at the design of geoinformation products with a specified quality. An analysis of the cadastral situation (Navratil *et al*. 2005a) showed that the quality aspects for different users of cadastral data vary dramatically and cannot be matched to the quality parameters used in metadata.

3.2. *Legal aspects*

Legal issues are an obvious research topic in land administration. Frank always listened to people with a different background and this included people with a PhD in law, like Harlan J. Onsrud, during his time in Maine and later Christoph Twaroch and Hans

Mattson in discussions. He was and still is interested in the development of land rights and texts like the 'Sachsenspiegel' (Von Schwerin 1987), the most important law book of the Holy Roman Empire, to understand the construction and development of law and land rights.

The modelling endeavours that Frank initiated within his research group only found limited response in the international community (e.g. Lutz *et al*. 2002). However, he succeeded in creating a close working relationship between the people in his group and Christoph Twaroch, a surveyor with an additional PhD in law (Twaroch 1998). This step enhanced the possibilities of working on law-related questions in the context of cadastre. A direct result was the discussion of public-law restrictions following the Swiss example (Swisstopo 2015). The discussion of the Austrian situation showed the need for such a cadastre (Weiskirchner 2014) and addressed connected research questions like the spatial delineation (Navratil and Spangl 2012).

Starting from economic concepts developed by Adam Smith, Douglass North and Hernandez de Soto, Frank formulated a request for simpler laws (Frank 2008). Following this approach, the idea of a simple cadastral model, a cadastre stripped of administrative complexity, was developed (e.g. Polak 2015). The advantage of such a model would be that the core processes would become visible. This would allow separating basic processes that are necessary for any kind of implementation and auxiliary processes that are required for a specific cadastral product. The latter kind of processes would not be necessary if the connected product, e.g. a 3D representation of land rights, is not suitable for a specific country. Apart from colonial influences, current implementations of cadastres show primarily where the advisors came from instead of the requirements of the nation. Greece is a good example for this problem (Markatos 2014). Navratil and Frank (2008) used the idea to clearly show how expropriation works. A full model of a simple cadastre does not yet exist.

3.3. *Organizational aspects*

The simple cadastre mentioned in the last section would also be a tool to identify organizational structures. Everything that is not required by the simple cadastre is part of the administrative overhead. A separation between these two aspects can help to identify points where efficiently can be improved by reducing administrative overheads.

Frank started the discussion on organizational aspects quite early. In 1988, he analysed the situation of LIS in the USA (Frank 1988). He compared the situation with the situation in central Europe and found four major problems: the lack of trained experts, the lack of a solid theoretical basis (which, according to Frank, had both been reported missing earlier by Jack Dangermond), the focus on specialized systems and an inadequate quality of the terrestrial reference frame.

A large debate in the last 20 years has been the discussion if cadastre and land register should be organized as a single institution, or in the form of two separate institutions. Andrew U. Frank did not publish explicitly on the topic but referred to concepts like business reengineering (Hammer and Champy 1999) during discussions to point at a critical issue: Changes in organization are only useful if they increase the efficiency by improving the processes and the costs of the change are compensated by these improvements within a reasonable period of time. While the Austrian decision is

quite clear (cadastre and land register fall under two different types of law, public law and private law, with different procedures and principles), other countries adapted their organizations, e.g. Sweden or Hungary. A comparison of the costs (financial and temporal) for the land owner to subdivide his parcel showed no significant difference between Sweden and Austria (Schallert and Navratil 2012) but the costs of sustaining the organization(s) were not included in the discussion.

3.4. *Economic aspects*

Frank also stressed the importance of economic considerations. He analysed the economic transformation of National Mapping Agencies from governmental departments to companies following the rules of a private market (Martínez-Asenjo and Frank 2001, 2002). This analysis was done in the context of an economic analysis for the Austrian Federal Office of Metrology and Surveying (BEV) and proposed an open-access approach for geodata (Frank 2003). This was approximately 10 years before the debate on open government data began and the political leaders did not agree at that time. However, later recent analysis by the BEV showed that the number of users increases dramatically after reducing the fees (BEV 2015, pp. 18–19).

The work for the BEV was done in a phase where Frank tried to analyse the value of geographic information. He started working on the topic in the 1990s when he tried to motivate practitioners to think economically and not only technically (e.g. Frank 1995, 1996c). Later, he published some ideas together with Alenka Krek (e.g. Krek and Frank 1999b, 1999c, 2000). He oversaw master thesis on economic questions related to cadastral surveys (e.g. Tanzer 2000) and dissertations in similar topics (e.g. Staudinger 1999, Krek 2002). The interest led to participation in the COST action G9 project (see Section 4). Frank later criticized the globalization of economic concepts using the example of a cadastre: In arid regions, water rights represent more value than land ownership and buildings erode more quickly and this contradicts the generally assumed idea of capital formation by appropriation and improvement of land (Frank 2007). Thus, an economic theory of land administration must be able to account for local variations. He did not follow up on this idea. However, he is still interested in economic questions and encourages students to investigate such questions (e.g. Muggenhuber 2017).

3.5. *Combines aspects*

Not all of Frank's questions fit exactly one of the above categories. Already the topics discussed so far were sometimes indirectly related to a second aspect although they had a clear focus on one aspect. This is not always the case. Throughout his career, Frank tried to merge apparently independent topics and concepts. Thus, he inspired cross-sectional cadastral approaches like the discussion of the importance of the area in a cadastre from a technical, legal and economical perspective (Navratil and Feucht 2009) or work on the necessity of a 3D-cadastre in Austria (Hackl 2007) and the implementation of cadastres of public-law restrictions (Navratil and Spangl 2012). 3D cadastres and cadastres of public-law restrictions combine legal and technical aspects and this combination triggered his interests. In connection to decision-making, the differences between technical and legal processes were discussed in his group (Navratil 2008). However,

decision-making was no new topic in the group, since it had, for example, been already analysed over a decade before by Frank *et al*. (1994) in the context of parcel shape and size as required by building authorization. It is obvious that land administration research will have to deal with an increasing number of research questions connected to more than one aspect. This will require interdisciplinary research groups.

4. National and international research activities

After his initial phase in the USA, where national initiatives were major milestones, Frank's research activities were accompanied by international cooperation. He saw theoretical analysis as a means to achieve a better understanding of systems and this could then be used to create standards for improved interoperability. He supported the Open Geospatial Consortium (OGC) actively in the late 1990s through the GIPSIE project (GIS Interoperability Project Stimulating Industry in Europe) funded by the European Commission. The goal was promoting GIS interoperability in Europe by (Kuhn 1999)

- informing the European GIS community about the OGC,
- representing European interests within OGC,
- providing a discussion forum and
- coordinating European contributions to the OGC specification development.

Based on ideas from computer science (e.g. Backus 1977), he and his group developed a theoretical approach to prove the correctness of the abstract specifications by using algebraic models instead of Unified Modelling Language models (Winter and Nittel 2003). As a tool, he promoted the functional programming language Gofer (and later Haskell) with Werner Kuhn in Vienna. Although OGC decided to develop a different testing strategy, the efforts of the GIPSIE team still enabled European researchers and companies to participate in the discussions within OGC.

The focus shifted more towards cadastral issues in the COST action G9 project 'Modelling Real Property Transactions'. On a national level, analysis of core processes had been performed earlier, e.g. in the project 'Cadastral System in Haskell', funded by the Austrian National Bank. The COST action G9 performed similar analysis on an international level and aimed at establishing a method of modelling transactions on the land market to make them more transparent. This included issues of comparison and comparability of processes in European land administration systems. One of the meetings organized during this project was the joint conference 'Standardization in the Cadastral Domain' together with FIG – International Federation of Surveying, December 2004 in Bamberg, Germany (Van Oosterom *et al*. 2006). This meeting was one of the steps of an FIG working group towards the LADM, an ISO standard for modelling cadastral systems (Lemmen and Van Oosterom 2013). The COST action focused on processes and Frank's key questions were connected to semantics, costs and efficiency: What do we get for which amount of money and how long does it take? He wanted to identify the elements that can be compared across systems (Frank 2006). The results of these discussions were summarized by Stubkjær *et al*. (2007).

A local Austrian initiative that Frank supported but never joined was the informal discussion group Round Table Land Administration with members from TU Vienna, University of Natural Resources and Life Sciences Vienna (BOKU) and the BEV. The

group wrote a number of papers for conferences and journals and published a book proposing a mass appraisal system for Austria.

Frank supported training of surveying experts in less developed countries if possible. He participated in the educational project MasGeo in Morocco financed by the European Union with the goal to graduate more students with a master degree in geoinformatics to satisfy the growing demand from the private and public sector. This connected to his experiences in 1988, when he found that a lack of trained experts restrained development of LIS in the USA (compare Section 3.3). He later supported a similar project called EduLAND2 in Ethiopia together with BOKU and financed by the Austrian Partnership Programme in Higher Education and Research for Development.[2] The goals of this project were establishing a Land Administration Competence Centre at Debre Marcos University in Ethiopia, supporting the university in the starting phase of the land administration curriculum, facilitating joint research activities between Austria and Ethiopia and conducting short-term training of students and staff to create local expertise.

5. Conclusions

The discussion showed that Andrew U. Frank performed, guided and initiated widespread research in the field of land administration. He saw land administration as an obvious application of GI technology for surveyors, who traditionally operate these systems in various countries. While he also investigated other applications, he worked on land administration-related questions throughout his career. Another reason for this is probably the diversity of problems related to land administration. It is a legally based, economical system with a technology-driven implementation that influences the social reality of citizens. This corresponds to Frank's widespread research interests, which cover semantics, reasoning, modelling, communication and much more.

Frank introduced new research methods in land administration research. He was among the first to model land administration systems with mathematical tools. Apparently, the generations before him assumed this to be too complex to be achieved but the rapid evolution of computers in the 1980s and 1990s allowed the creation and analysis of such models. He gained interesting insights from these models and initiated new lines of argumentation from his conclusions, e.g. the measurement-based GIS or the recommendation of freely available high-quality land administration data.

Frank was not actively involved in the creation of standards like many of his colleagues in the last 30 years. This does not reflect a disregard for standards as shown by his support of OGC in Europe. However, having too many different questions in mind, he was not patient enough to sit through the numerous meetings required to create a standard. However, whenever he saw an interesting research question, he was willing to provide the theoretical basis for standardization.

A lesson that can be learned from Frank's career is that research in land administration is multidimensional. A factor for his success was probably the fact that he included people with various kinds of education in his team: surveying, mathematics, spatial planning, computer science, geomatics, electrical engineering, economy, law and even psychology. While it is easy to achieve this diversity in a large research project, Frank achieved it in a rather small research group, albeit not covering the whole range all the time.

Notes

1. Orig.: Viele Anwendungen sind ökonomisch nicht attraktiv, wenn die grundlegenden Daten selber erhoben und laufend gehalten werden müssen.
2. https://appear.at/en/projects/current-projects/project-websites/project113-eduland/.

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