Visualizing an Emerging Mobility Business Ecosystem

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***Abstract*—Visualizing data is a widely used approach to derive value from data. Within the context of business ecosystems visualizations have proven to enable ecosystem stakeholder to take better-informed decisions. Thereby, the collection of relevant data is often referred to as a major challenge. In this paper, we present knowledge extracted from visualizations of an emerging mobility business ecosystem. Our research approach consists of the identification, assessment, and evaluation of open Internet data sources, followed by the extraction and visualization of this data. We identify groups of participating organizations, the main relation type between organizations, and the role of mobility information and mobility service provider as two new organization types within the mobility ecosystem.**

***Index Terms*—Ecosystem, Visualization, Knowledge Extraction, Internet data sources, Connected Mobility**

I. Introduction

Digitization – and its advancements – has long reached cities including their outskirts and rural satellites and is changing urban mobility. Cities transforming into Smart Cities, whereby Smart Mobility is often recognized as the most common indicators of Smart Cities [1]. Digital technologies are continuously integrated into vehicles, traffic systems, and infrastructure [2], and are thereby changing the mobility demands of humans. The variety of digital technologies ranging from mobile applications to Internet of Things (IoT) devices integrated in existing infrastructure. Thereby, mobility applications provide timely information on the traffic situation, the option to buy tickets for public transportation online, or the usage of shared mobility services such as car sharing, bike sharing or ride sharing, to name just a few. IoT devices such as sensors make information of occupied or free parking slots available or report about the carbon dioxide (CO2) level on roads with heavy traffic [3].

Established mobility actors, such as automotive OEMs, their Tier 1 to 3 parts supplier, but also public transportation agencies, are challenged especially by technology companies using their advantage of applying new technologies – such as augmented reality or artificial intelligence – to urban mobility. Tech giants such as Google and Apple are entering the mobility scene by developing self-driving cars and pushing autonomous driving ([4], [5]) exhibiting disruptive, innovative characteristics. Thus, new actors enter and transform the existing mobility markets that are geographically focused on specific metropolitan areas. As a result, new mobility business ecosystems are currently emerging. With new technologies being used and applied, also mobility related legislation has to be discussed and adapted, turning cities, public institutions and their governments into actors of these ecosystems.

Besides commercial mobility providers, also cities, their public institutions, and their governments are under pressure to address these challenges and to understand the emerging structures within mobility ecosystems to make informed decisions [6].

Visualizations of business ecosystems have proven to support decision makers within their ecosystem related tasks [7] and is widely applied in research (cf., [8], [9]). Visualizing data can help to derive value from the ecosystem data, e.g., spot anomalies, identify keystone and niche players of the ecosystem, or recognize patterns and trends [10].

Thereby, ecosystem data is large and heterogeneous [11], ranging from technology-related data about applied standards and platforms to use patterns of mobility service apps and their user types. When focusing on the business aspects of these emerging mobility ecosystems, information about service providers, their strategies, partnerships and offered solutions, and cooperative initiatives become relevant [12]. Data comprising this information can come from various sources, such as existing databases of the established mobility ecosystems, newspaper articles or blogs addressing recent development within the ecosystem, but also company and institutional web presences and publications. Few research has looked into the issues related to data collection in emergent business ecosystems ([13], [14]). This poses particular challenges for utilizing visualizations for ecosystem analysis or business development [15].

The presented research is part of a smart city initiative pursued by a European city. The general goal of this paper encompasses a procedure for the identification, assessment, and selection of relevant Internet data sources to extract and visualize suitable data to discover knowledge about the emerging connected mobility business ecosystem. The research was conducted in close collaboration with an ecosystem stakeholder of a publicly funded non-research institution.

The remainder of the paper is structured as follows. In the next section related work on modeling and visualizing business ecosystems and quality based selection of Internet data sources is presented. Section III describes the research approach followed. After a detailed description of the quality-based selection of Internet data sources in Section IV, the derived knowledge about the mobility ecosystem using visualizations (see Section V) is presented. Finally, discussion and conclusion are comprised in Section V.

II. Related Work

A. Business Ecosystem Modeling and Visualization

Since the introduction of business ecosystems by James Moore in the mid-1990s, who defined it as a collection of companies interacting [16], the concept has been widely studied [17]. The initial definition was extended describing the role of companies as "suppliers, distributors, outsourcing firms, makers of related products or services, technology providers, and a host of other organizations" [18], all affecting business success and failure of companies active within the business ecosystem. Furthermore, business ecosystems constantly evolve, exhibiting a dynamic structure [19], with not only companies but also human actors, entering and leaving the ecosystem, which "are interconnected through a complex, global network of relationships" [11].

Especially the Internet of Things (IoT) business ecosystem modeling recently gained researchers attention, addressing business ecosystem design methods [20], presenting a framework to fully understand the complex IoT ecosystem, or as a use case for a visual approach to understand the business ecosystems [13].

To foster the understanding of business ecosystems, Park et al. presented a visual analytic system [21], addressing three identified salient design requirements by tailoring the supply chain management ecosystem. The described system provides multiple views in an integrated interface enabling users to interactively explore the supply network and additionally providing data-driven analytic capabilities. Five network layouts are introduced, which are a force-directed, circular or chord diagram, treemap, matrix, and substrate-based layout. Thereby, all visualizations provide interactive features, such as clicking, dragging, hovering, and filtering. This work is based on extensive research in the area of modeling, visualizing and analyzing business ecosystems (cf., [11], [21], [22], [23], [24], [25]).

In this previous research, a data-driven approach is applied to foster the understanding of the dynamics within the mobile ecosystem, using a cumulative network visualization [25], or dynamics within the business ecosystem applying a novel bicentric diagram to visualize the relation between two focal firms [12]. This novel visualization is described and evaluated in [13].

B. Quality-Based Selection of Internet Data Sources

Depending on the purpose and context of an information system, data can come from various sources [26]. One of the data sources nowadays often used are Internet data sources. Thereby, the number of available Internet data sources is vast with varying quality. Thus the approach of how to evaluate these type of data sources has gained researchers' attention.

Stróżyna et al. defined six quality measures to assess sources for a maritime system: accessibility, relevance, accuracy and reliability, clarity, timeliness and punctuality, and coherence and comparability. Each of them was assigned with a weight and then graded with either a 3 (high), 2 (medium), 1 (low), or N/A (not applicable). With a formula, a final score was determined, and every source with a score about a previously assigned threshold was selected [27].

Naumann et al. proceeded similary, but instead of assigning constant weights to the quality measures, they created a linear problem for each source to find suitable weights for the quality measures [28]. Wang et al. defined less but broader quality measures: accessible, interpretable, useful, and believable [29]. And Batini et al. mention the cost of data quality in terms of opportunity costs and process costs [30].

III. Research Approach

We conducted this research within a time frame of 1.5 years, starting in October 2016. We base the identification, assessment, and selection of suitable Internet data sources and the following data extraction and visualization on input from research (literature review) and feedback from an ecosystem stakeholder outside the research community whom we interviewed twice within the research process. The overall research approach is visualized in Figure 1.

A. Problem Identification and Motivation

The research project is part of a Smart City initiative pursued by a European city to support the digital transformation in the area of Smart Mobility. One of the project's aims is to contribute to the establishment of the currently emerging and shaping mobility business ecosystem consisting of mobility providers, service providers, developers, and mobility users. Therefore, we conducted several group discussions with stakeholders of the ecosystem prior to this research work. In these workshops, we identified the stakeholders' need to better understand the emerging mobility business ecosystem. On the basis of these workshops, we sharpened our research approach by conducting a literature review, considering various journals and online catalogs (i.e., Scopus, IEEE Xplore Digital Library, ACM Digital Library, and Google Scholar). Related

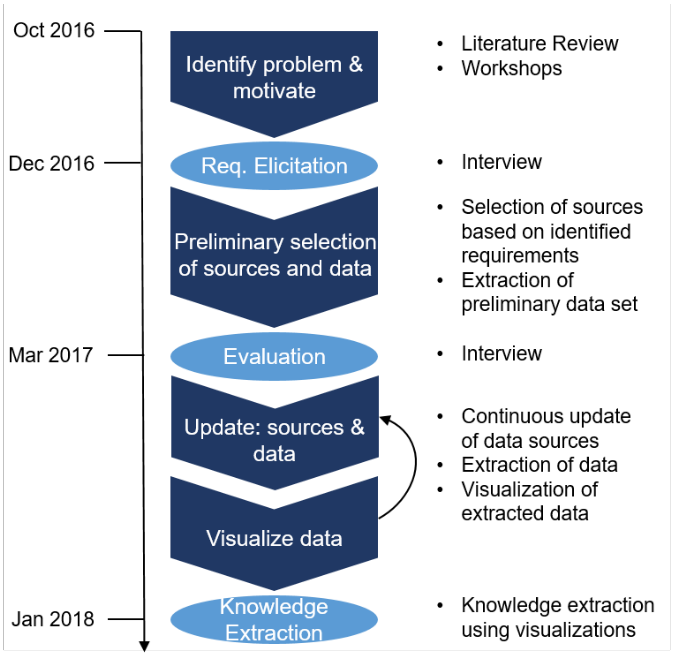

Fig. 1. Research Approach.

work about business ecosystem modeling and visualization but also on a quality-based selection of Internet data sources is documented in Section II.

B. Requirement Elicitation

As one main stakeholder of this smart city initiative, we identified a publicly funded non-research institution interested in strengthening the mobility business ecosystem by organizing mobility networking events and initiating and supporting innovative mobility projects with funding. Within a 30 minute semi-structured interview conducted in December 2016, relevant entities of the mobility ecosystems and their relations were identified. Thereby, the specific metropolitan area in the focus of the Smart City initiative was considered.

C. Preliminary Selection of Sources and Data

Based on the received stakeholder's input, suitable Internet data sources were selected, prioritized and preliminary data was extracted. Therefore, we first identified open Internet data sources, which we assessed in detail to finally select 12 data sources, from which we extracted 247 entities and 300 relations. The assessment process is described in detail in Section IV.

D. Evaluation

The preliminary selected Internet data sources and the extracted data were evaluated within a 60-minute semi-structured interview with the same stakeholder in March 2017. Together, the prioritization of sources was adjusted, and the existing data set evaluated. We used this evaluation step to ensure the practicability of the followed approach and the targeted results.

E. Update: Internet Data Sources and Data Set

The received feedback was used to select further suitable Internet data sources and continuously extract relevant mobility business ecosystem related data. Before the second interviews, the number of entities was large compared to the number of relations. Hence, within this process step, the focus lay upon finding the latter. Therefore, four sources were added to the 12 already in use. These four sources amount for an additional 198 relations and 24 entities. The total amount of entities and relations extracted counts 271 entities and 498 relations between these entities.

F. Visualize Data

The extracted data set was continuously visualized using visualizations presented in research within the context of ecosystem visualizations [21]. Namely, (a) chord diagram layout, (b) treemap layout, (c) matrix layout, and (d) force-directed layout. All visualizations provide interactive features, such as filtering, clicking, or hovering (see Section V). Based on the visualizations the data extraction was adapted, e.g., a specific search for Internet data sources comprising information about organization's relations of documented entities.

G. Knowledge Extraction

In a final step, the visualizations were used to derive knowledge about the mobility business ecosystems of the metropolitan area in focus. The results are presented in Section V. Thereby, the extracted knowledge is documented in connection with the visualization type which was used. Thereby, we followed an approach presented in previous research [15].

IV. Quality-Based Selection of Internet Data Sources for Mobility Ecosystem

The selection of Internet data sources and the extraction of data was conducted in two phases. Gathering early stakeholder feedback ensured the appropriateness of the approach on how the sources were selected and which data was extracted. After the evaluation of the preliminary selected Internet data sources and extracted data, the process was iteratively repeated using the data visualizations as further evaluation criteria.

A. Internet Sources Related To Connected Mobility

The Internet sources of interest for the connected mobility ecosystem can be divided into three categories.

First, a significant number of databases comprising collections of companies offering products or services related to mobility already exist. The information about ecosystem entities provides the basis for our research. Depending on the database, further information of the comprised entities such as the current CEO, the address of the headquarter, or a general description of the field of activity is presented. These databases are available as either open source – meaning the data is freely accessible and reusable without an additional authorization step –, open source but enforce a registration without charge, or closed data sources which require registration, authorization, and non-free access [27].

The second category is news feeds, blog posts, or web articles, which describe recent development of the mobility ecosystems. These sources can also be categorized as above, but most often they are openly available or with optional registration.

The third category is information published online by mobility ecosystem companies on their public appearance or in public reports: documenting the economic situation and company's strategic decisions to name just a few. Using two search engines, we first identified 12 suitable Internet data sources, which we enriched to 16 sources in the second phase of source selection. We focused within both steps solely on open access sources.

To ensure a broad background of sources, different search terms were used within the search engines. They ranged from rather granular ones like "connected car database", "mobilität startup datenbank" (mobility startup database), or "blog über mobilität" (blog about mobility) to basic queries such as "company database" or "automotive database".

B. Internet Data Source Assessment

As a starting point, we collected possible requirements that were gathered during the two stakeholder interviews. Additionally, further possible quality measures were extracted from previous research ([27]–[30]). In the end, the identified Internet sources were evaluated using the following criteria: (a) data access - we focused on openly available Internet data sources, (b) platform focus - the data source should at least contain data that is relevant for a mobility business ecosystem within the Smart City project, (c) geographic focus - the content of the source should contain data that is relevant for a local mobility business ecosystem, (d) data scope - what kind of data is covered regarding (d1) entities - with attributes such as name, legal type, headquarter, CEO, description, and (d2) relations - with attributes such as type of relation, involved partners, date (in case of a funding), (e) data extraction - how easy can the relevant data be extracted from the source, and (f) data validity - can the source be trusted.

All identified and later used Internet data sources provided information in either English or the local native language (in our case: German). Thus, an assessment based on the language was not conducted.

C. Data Extraction

After identifying the most promising Internet data sources, the data had to be extracted. This process consisted of one step –the extraction itself–, with an optional step beforehand, where the data was downloaded from the source in a compressed form, e.g., as a *.csv* or *.xlsx* file. In all cases, within this research, the data was copied manually due to the different data formats.

V. Mobility Ecosystem Knowledge Extraction using Visualizations

For the data collected, we used a Knowledge Management System application development platform which rests on a Hybrid Wiki approach, as described in [31]. The system contains features for data management as well as collaboration and decision support.

The ecosystem data is visualized in four visualization layouts, (a) chord diagram layout, (b) treemap layout, (c) matrix layout, and (d) force-directed layout, as shown in Figure 2. For this, we used layouts presented in previous research within the context of analyzing a supply chain network [22]. The visualizations in use provide interactive features, such as clicking to gain additional information about the ecosystem entities, hovering for highlighting, and filtering to focus on specific aspects of the ecosystem. In addition, a searchable list view of all entities of the ecosystem plus a view comprising detailed information about each entity are available. Thereby, each visualization has two elements: the first element provides the link between the data model and the visualizations. The second element is the specification of the visualization for which we use a declarative visual language. The main building blocks, which enable static and dynamic visualization features, are a) data, including data but also all data transformations; b) marks, covering the basic description of the visualized symbols, e.g., shape and size of a node; c) scales, containing visual variables, such as the color coding; d) signals, including the different interaction options, e.g., dragging and dropping of entities; and in some instances e) legends. The proposed approach provides the feature of adapting the visualizations in case of a data change at run time.

For the knowledge extraction, we followed the "knowledge flows through visualizations" as presented in [15]. Insights about the mobility business ecosystem that can be derived through the visualizations include:

- Automotive OEMs show a high interest in Mobility Service Providers with funding and cooperation relations (CDL)
- Mobility Information and Mobility Service Provider – as two innovative groups of ecosystem entities – are connected through collaborations indicating a complementary orientation (CDL)
- Strongest category of organization is part supplier which comprise Tier 1 to 3 supplier, illustrating the dependencies of a large number of SME companies from automotive OEMs (TML)
- The part supplier group of organizations is followed by Mobility Service Providers (TML)
- The dominant relation type of the mobility business ecosystem is "supplied by" (MXL)
- Automotive OEMs comprises the largest amount of relations as they are still a focal part of the mobility business ecosystems (MXL)
- Automotive OEMs largely trust the competencies of the same suppliers but invest in competing companies/startups (MXL)
- In several cases, suppliers of the Automotive OEMs have some form of relationship with each other (FCL)

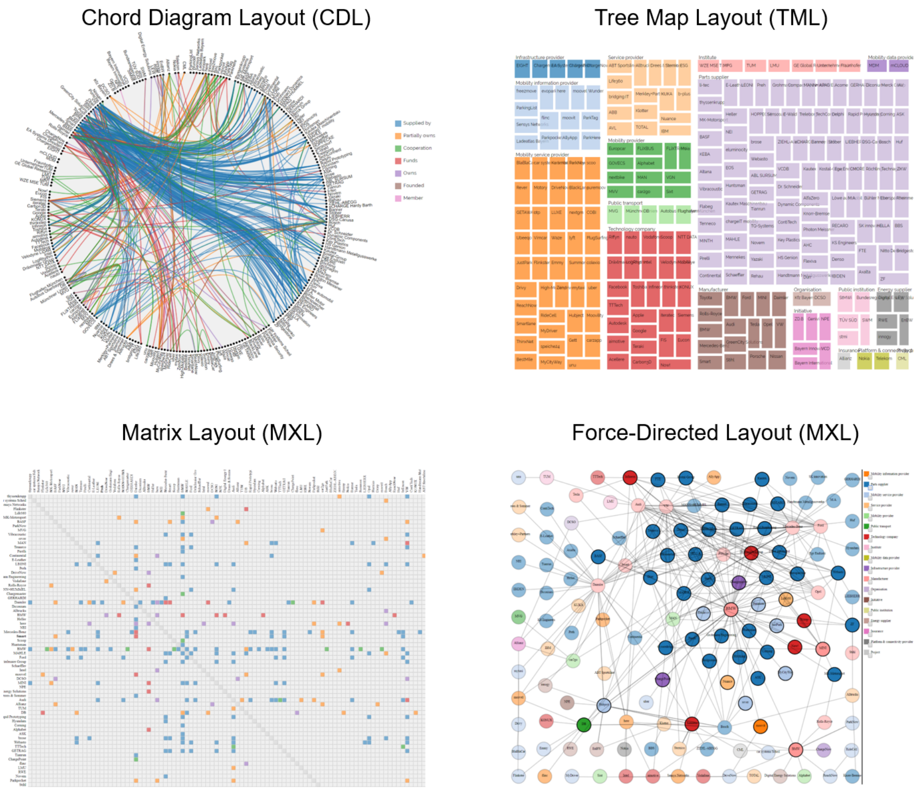

Fig. 2. Visualizations Techniques applied to the Extracted Mobility Business Ecosystem Data.

VI. Discussion and Conclusion

The aim of this paper was to present a research approach to identify, assess, and select suitable Internet data sources to extract data about an emerging mobility business ecosystem. This data was used for interactive visualizations which can be used to extract knowledge about the ecosystem. We conducted our research in close collaboration with one ecosystem stakeholder to ensure the practicality of our approach. Further, we applied the presented research approach for one specific metropolitan area in Europe.

Regarding the assessment of Internet data sources, the applied criteria are not comprehensive. For example, timeliness was not used due to the fact that only some databases provided information on how frequent updates are made to the data. Nevertheless, for a better understanding of the evolution of the mobility business ecosystem, timeliness seems like a promising and relevant additional criterion to include in future.

At the moment, the proposed approach has not been validated in other areas or domains. Nevertheless, we believe the knowledge extracted from the provided visualizations can help ecosystem stakeholders, both commercial and governmental ones, to take better-informed decisions. As the mobility business ecosystem is currently emerging, the presented approach is an ongoing one. Continuously Internet data sources need to be identified, assessed and used to extract suitable data to provide up-to-date visualizations.

Our presented work is based on manual extraction – providing a noticeable limitation due to the time-consuming work – and future work may include (semi-)automated data extraction process steps, such as provided with Natural Language Processing. This would enable a larger amount of data being pre-processed leading to a more efficient process. Also, the inclusion of further stakeholder groups for the knowledge extraction seems to be promising future work.

Acknowledgement

This work has been sponsored by the German Federal Ministry of Education and Research (BMBF) grant BEEx+ 01IS17049. This work is further part of the TUM Living Lab Connected Mobility (TUM LLCM) project and has been funded by the Bavarian Ministry of Economic Affairs, Energy and Technology (StMWi) through the Center Digitisation.Bavaria, an initiative of the Bavarian State Government.

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