Leibniz Universität Hannover

Wirtschaftswissenschaftliche Fakultät

Institut für Wirtschaftsinformatik

Development of a Decision Support System for Carsharing Optimization

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M. Sc.)“ im Studiengang Wirtschaftswissenschaft der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

Vorgelegt von:

Name: Broihan   Vorname: Justine

[redacted] [redacted] [redacted]   [redacted] [redacted]

Prüfer: Prof. Dr. M. H. Breitner

Ort, den Hannover, 28. September 2016

Abstract

Today, carsharing organizations are faced with a multilayered problem setting. With an increasing number of strategies to choose from decision support becomes more valuable to carsharing service providers. However, decision support is often subject to high expenses and a lack of graphical support. Therefore, the application of non-commercial solvers, i.e. BONMIN 1.8, Couenne 0.5, and SCIP 3.2, to the decision support model proposed by Sonneberg et al. [52] is tested. It is found that currently no non-commercial solver is able to provide adequate solutions to the model. Additionally, a decision support system is developed which focuses on the creation, visualization, and comparison of different optimization problem settings.

Keywords: carsharing, decision support system, Ruby on Rails, non-commercial solver application, SCIP

List of Contents

1 Motivation and Relevance

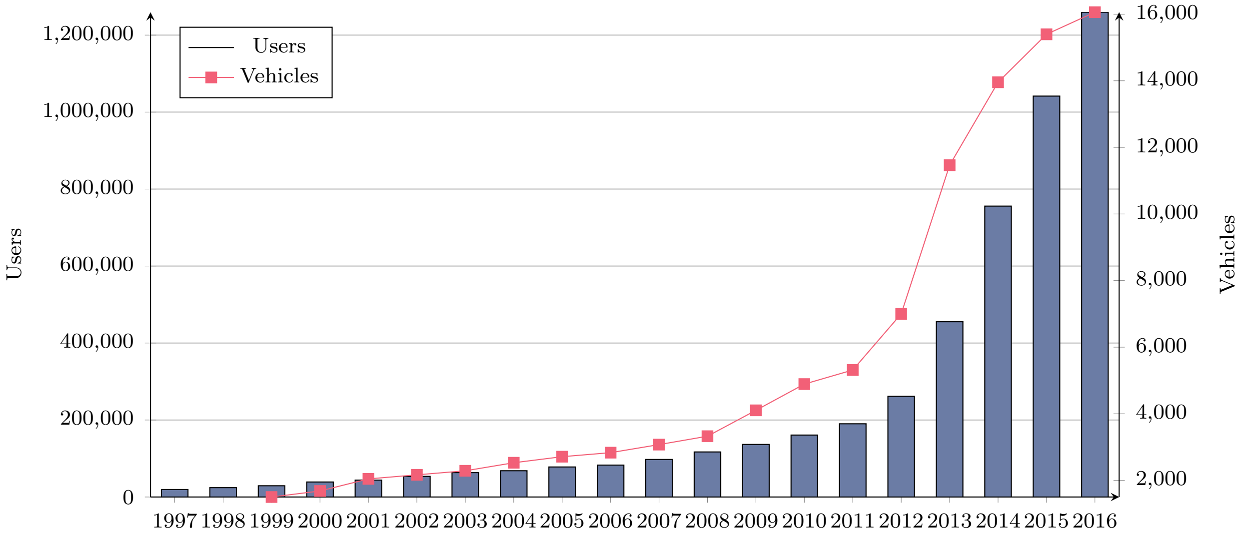
During recent years, increasing pressure on ecologically friendly locomotion emerged various innovations as an alternative to conventional car ownerships. Among hybrid and electrical propulsion methods the idea of sharing means of transportation has become popular [58]. Those sharing concepts initiated the commercial provision of on-demand vehicles across a given area as a new business model. It is observed to have positive effects on urban mobility as it enables a more efficient utilization of vehicles [36]. It also reduces private car ownerships and thus results in a decline of traffic and occupied parking spaces [13]. Additionally, the average driven kilometers of persons formerly owning a vehicle is reduced by up to 27% [39].

Initially, carsharing was realized as a rationing tactic by the U.S. government during World War II and later continued commercially [49]. Nowadays, carsharing organizations face growing market competition due to an increasing number of providers entering the market. Additionally, governmental prerequisites, such as maximum fine dust and carbon dioxide (CO_2) emissions, are further legal impediments on providing a profitable and reliable carsharing service. Approaches towards the deployment of electrical vehicles and heterogeneous fleets are instrumental in meeting those requirements. However, decisions on reorganization are required to be well-founded to maintain the system's profitability. Furthermore, carsharing organizations have an obligation to adjust their services to current and future external factors. As illustrated in Figure 1, a growing popularity of carsharing and increasing user rates constitute constant challenges to service providers. Numerous strategies concerning the adaption to those effects exist. These plans involve an expansion of carsharing networks or relocation of vehicles to meet a higher demand. However, the strategy selection process of decision makers currently relies on intuition and consequently, often results in non-optimal outcomes [20]. Therefore, detailed planning and thoughtful management practices are required [14] as the attractiveness of carsharing is also determined by its level of service and its associated costs [9].

A solution to inadequate decision making is provided by so-called decision support systems (DSSs). Mathematical optimization models and discrete event simulations (DESs) help decision makers to choose appropriate business strategies on well-founded groundwork. Hence, it provides a feature that decision makers can rely on. However, DSSs are costly as they are subject to expensive software and mathematical solver licensing. This may lead carsharing organizations to turn down purchasing plans. Additionally, mathematical DSSs tend to be user-unfriendly as they often do not provide tools for automatic solution processing supported by a graphical user interface (GUI). Yet, visualization and strategy comparison are essential factors in decision-making processes.

Against the background of high-cost DSS deployment, this thesis is focusing on the reduc-

Figure 1: Carsharing user rates
According to Bundesverband CarSharing [10]



tion of deployment costs by applying standalone non-commercial solvers to the mathematical decision support model (DSM) by Sonneberg et al. [52]. Further, the problem of missing tools to process optimization results is tackled by developing a DSS with regard to visualization and comparisons. Recapitulating, this thesis is concerned with the following research questions:

RQ 1: How can non-commercial solvers be applied to the DSM proposed by Sonneberg et al. [52]?

RQ 2: How can a GUI for the model introduced by Sonneberg et al. [52] be designed with regards to visualization and solution comparison?

In order to answer these research questions, this thesis is organized as follows: A literature overview on the development of a DSSs with regard to the concepts of carsharing is provided in subsection 2.1. It gives an inside into previous research on DSMs and DSSs. Subsequently, the underlying programming concept applied within the development process of this thesis is presented in subsection 2.2. Eventually, main research is documented in section 3 and section 4. Therefore, the DSM by Sonneberg et al. [52] is presented by analyzing its specifications and assumptions (subsection 3.1) followed by its notation and formulation (subsection 3.2). Upon those findings, a requirements profile is derived within the scope of subsection 3.3, and possible implementations are provided in the form of mockups.

Subsequently, subsection 4.1 presents the back-end computation, and subsection 4.2 is concerned with the actual implementation of the mathematical DSM. Therefore, the system architecture is derived in subsection 4.2.1, followed by the presentation of all primary functionalities that are implemented (subsection 4.2.2). A sample test suite is provided in subsection 4.2.3, and finally, subsection 4.2.4 presents the DSS in an application example. Findings, results, limitations, and recommendations are discussed in section 5. Finally, section 6 concludes and proposes potential future research.

6 Conclusions and Outlook

As growing environmental protection needs encourage research to develop alternative means of transportation and optimization strategies for existing technologies, decision support becomes more valuable to the management [14]. However, decision support is often subject to high expenses and a lack of graphical interfaces. Against the background of growing demand and utilization of carsharing services [10], this thesis focused on decision support for carsharing providers. Therefore, particular emphasis was put on a cost reduction for decision support and the corresponding development of a fully functional DSS for the model introduced by Sonneberg et al. [52].

Within the scope of this thesis, the appliance of non-commercial solvers to the model proposed by Sonneberg et al. [52] was tested. The objective was to reduce costs for solver and software licensing regarding DSMs and DSSs. Therefore, all currently available MINLP solvers (twelve) were evaluated with respect to commercial or non-commercial licensing and the availability of a standalone version. The latter was considered as it allows cost savings for algebraic modeling language software. Five of twelve solvers were found to satisfy both criteria, i.e. non-commercial or academic licensing and standalone availability. However, two of five solvers are only available to the developer's contributors. Consequently, the remaining three solvers, i.e. BONMIN Library 1.8, Couenne Library 0.5, and SCIP Version 3.2, were applied to the MINLP by Sonneberg et al. [52]. Repeated computations showed that none of the considered solvers returned adequate results. All computations were terminated by exceeding the given time limit of 36 hours. Since SCIP obtained the most promising results with a remaining gap of 11.36% and provides a shared memory parallelization extension, the model introduced by Sonneberg et al. [52] was applied to FiberSCIP in order to parallelize the solution process. Therefore, a significantly increased computing capacity was provided by Google's Cloud Computing [24]. Overall 16 virtual CPUs, each at 6.50GB RAM and 104GB memory, were requested. However, multiple computation attempts terminated without delivering a solution.

In order to show the general accomplishment of applying SCIP to the model introduced by Sonneberg et al. [52], a small data sample was chosen to be optimized. The returned solution was found to be optimal at a remaining gap of 0%. Therefore, the size of the data samples, required to provide practicable results, and the model's non-linear nature are assumed to cause the unsuccessful application of non-commercial solvers to the model. Since a further segmentation of data samples into smaller instances is found to be inconvenient, a reformulation of the model into a MILP is assumed to result in more satisfying outcomes and faster computation for both, commercial and non-commercial solvers.

Further, the development of a DSS for the model introduced by Sonneberg et al. [52] was the objective of this thesis. As the application of a non-commercial solver was found to be unsuccessful, the back-end computation is subject to the commercial solver ANTIGONE Version 1.1 and GAMS 24.5.6. ANTIGONE is found to return solutions to the problem setting in a significantly shorter amount of time and thus provides a suitable alternative to the considered non-commercial solvers.

Following the software development procedure model proposed by Royce [45], a DSS, which allows the creation, visualization, and comparison of individual optimization problems, was developed. Special focus was put on a user-friendly parameter and data input as well as on the visualization and comparison of different optimization settings. Therefore, a requirements profile with respect to a user-friendly and practicable application of the DSS was derived by analyzing the mathematical model and its restrictions. Also, the DSS's specifications and characteristics were determined and translated into an entity-relationship model. For the database system architecture, the entity-relationship model was translated into a relational database model. All main functionalities were presented and a comprehensive test suite of overall 319 tests with respect to unit, controller, view, integration, and request testing was applied. To show the appliance of the developed DSS, an application example was provided.

Further research and development may consider a reformulation of the model proposed by Sonneberg et al. [52] into a MILP. It allows the application of further non-commercial solvers which are able to solve linear but not non-linear problems to the model. With regard to the DSS, an implementation of computation capacity utilization is expected to result in a benefit for the operator. Additionally, a feature for an individual comparison of selected optimization settings is assumed to improve the DSS's quality further.