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How to define and measure modal share?

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Abstract

Modal share is a well-known and regularly used indicator in transport research and mobility management. Despite its general use in policies and plans, the modal share is a rather under-researched topic, particularly from a scientific point of view—the lack of commonly used terminology and methodology cause difficulties in creating a comprehensive analysis. Hence, systematic literature review was carried out to reveal the different measuring and calculating methods of modal share. We found that apart from the methodological questions of measuring the performance of transport modes, the methodology of measuring walking—an essential yet hard-to-measure transport mode—is problematic and raises technical issues as well. The key findings of the study are that the option for novel transport modes have to be measured as the 'traditional' ones, and taking walking into account cannot be omitted.

Keywords: modal share; measuring methods; multimodal/intermodal transport; terminology; non-motorised mobility; resilient cities

1. Introduction

The purpose and essence of transport is the movement that allows people, goods, and information to get from one point in space to another. In order to implement, operate and develop the transport process, it is necessary to constantly examine the characteristics of passenger and freight transport, analyse the data, learn from the the findings and results, and monitor the constant changes in demand and supply characteristics. In case of the the day-to-day operation of passenger transport and logistics the analysis of transport processes are required on a higher level, such as organisation, town, city, region. A frequently used indicator is the modal share which expresses the relative performance of interrelated and separately operated transport modes. The modal share represents the share of a particular transport mode compared to the whole amount of trips made, passengers transported, or kilometres travelled. Despite its general

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use in policies and plans, the modal share is a rather under-researched topic from a scientific point of view. The lack of commonly used terminology and methods causes difficulties in creating a comprehensive analysis (Ungvarai, 2019). Although considering the modal share is necessary in several policy documents, such as sustainable urban mobility plans (SUMPs), and during the evaluation of traffic changes (Rupprecht Consult, 2019; Sundberg, 2018), the research and the long-term mobility and management planning methods related to modal share seem to be incomplete.

The term *modal share* appears in the scientific literature and in everyday use also, although it can be mixed with other terms, such as modal split and modal shift[†]. The term modal share and the phrase 'division of labour in transport'[‡] can also catch the essence of the concept. 'Division of labour' gives another dimension: the phrase assumes that the transport process can be divided and all tasks and this kind of 'employment' can be assigned to the most 'competent' and suitable transport mode that can perform the task efficiently considering actual boundary conditions (e.g. transport volume, available transport modes, capacity constraints, regularity of demand, topography).

The measuring and calculation methods of modal share are not unified. For instance, how to measure and calculate the modal share in multimodal or intermodal journeys (Matulin et al., 2009). A simple method may be applied: calculating modal share in which all the transport modes different from that the passenger used for the *longest time or distance* are neglected, or the calculation distributes the multimodal journey mode share according to the time/distance travelled during trips. The issue of measuring walking and non-motorized modes also needs studying. Measuring the amount of walking, as a major transport mode is problematic and raises methodological issues. Several questions, for instance how walking can be described as a separate transport mode despite its connections to other modes through access and egress trips are still needs to be answered. In addition, there is no generally accepted principle for handling some emerging soft transport modes, such as micromobility, electromobility, shared mobility whose roles are increasing in urban transport.

Hence, the research question of the study is how to measure and define modal share and related terms in order to offer a comprehensive methodology and terminology for a standard approach. The purpose of the study is to give a widespread review of measuring modal share. Another aim is to present the current heterogeneity and accompanying shortcomings of the field by collecting the data available at different organizations.

The structure of the paper is as follows: Section 2 review the scientific literature in the field. Section 3 presents the applied research methodology. In Section 4 the results are presented in detail, while Section 5 concludes the paper.

2. Literature review

During the research, a comprehensive and systematic scientific literature review was carried out to explore the measuring and calculating methods of modal share and the methods of measuring the use of particular transport modes.

The use of modal share cannot be narrowed down to a single topic. Modal share can be applied to evaluate the competitive position of rival transport modes (Altieri et al., 2020; Dolinayova et al., 2018; Jonkeren et al., 2011), analyse the effects of the rapidly spreading e-mobility (Astegiano et al., 2019; Kämper et al., 2016; Krier et al., 2021; Moreau et al., 2020), to estimate the economic (Blondiau et al., 2016) and environmental (Astegiano et al., 2019; Böcker et al., 2013; Fuller et al., 2013; Romero et al., 2019) impact of active mobility (Meeder et al., 2017), to study the effects of changes in fuel prices (Creutzig, 2014), to map the possible challenges that autonomous mobility could cause in the transport system (Kamel et al., 2019), and to investigate and analyse transport systems on a global level (Fountas et al., 2020; Mohammadi et al., 2018).

[†] Modal split is usually referred to as the third stage of the four-stage transport modelling method, i.e. the transport mode choice modelling, the allocation of trips in the matrix to different modes (Ortúzar and Willumsen, 2011). While modal split describes the performance changes of transport modes, modal shift stands for the 'intentional' changes, which are typically the results of planned transport policy interventions (Pálfalvi, 2009). Thus the terms modal split and modal shift should be avoided in studies comparing the performance of transport modes.

[‡] The term 'division of labor in transport' is used in post-socialist countries' scientific language almost as a synonym for modal share.

2.1. Peculiarities and application areas of modal share

The importance of measuring and calculating modal share is caused by the need to collect comparable datasets. Careful mobility and transport planning require an assessment of the current situation and the definition of travel characteristics (Rupprecht Consult, 2019; Sundberg, 2018), along with the absolute and relative performance of transport modes (e.g. passenger number, passenger kilometres, modal share in percents). An assessment of the modal share could be an important component of SUMPs, as the environmental and transport goals also need a baseline value relative to which all the improvements can be built—the neglected position of modal share is well exemplified by the finding that, although SUMPs could be a typical application area for measuring performance, surveys to determine modal share have been omitted in part or fully from a number of SUMPs analysed.

It is therefore advisable to use and (re)calculate the indicator of modal share at the:

- quantification of the effects of major transport-related interventions (e.g., infrastructure development, replacement of rolling stock, large-scale timetables changes, the emergence of new transport modes) and estimating the impact of the interventions on the performance of each sub-sector and mode;
- changes of external effects on the use of the transport system:
- economy: for instance, changes in fuel prices, economic expansion or recession (Blondiau et al., 2016; Wang and Monzon, 2016);
- society: for example, quickly spreading transport modes (Krier et al., 2021; Moreau et al., 2020);
- environment: the quantification of measures, phenomena, and impacts related to climate change and transport (Böcker et al., 2013; Jonkeren et al., 2011; Kämper et al., 2016);
- tracking and examining the effects of other significant, extreme conditions and impacts (e.g. terror attack, pandemic situation) (Bucsky, 2020);
- examining the connections inherent in the transport system;
- *monitoring the use of alternative and innovative, novel transport modes*.

2.2. Defining modal share

The definitions in the literature approach the question from several directions but conclude with similar results—the definitions also include aspects of passenger and freight transport.

- “For each transport sub-sector and transport mode, the inherent aim is to perform the task it is most efficient in at the social or economic level. i.e. the modal share (division of labour) presupposes conscious activity and the search and pursuit of the optimal employment of the available transport modes.” (Pálfalvi, 2009)
- Transport mode (or means of transport) shares to satisfy the overall demand for certain transport services; allocation of the transport services to the various modes or means of transport. (Gabler Wirtschaftslexikon, 2018)
- Provides information on the actual composition of traffic, including the shares of pedestrians and cyclists. (Franke, 1995)
- Splitting traffic between available transport modes, i.e. the mode choice. (Emberger et al., 2018)

A common shortcoming of the presented definitions is that they are not able to provide an in-depth interpretation of modal share; they only illustrate the significance of the defined term. The definitions also demonstrate the problem that the basis of comparison is uncertain—this also leaves a mark on the results of the applications. The basis of the calculation may be a complete travel chain, a single trip, the number of passengers or the passenger-kilometres travelled. Further issues are whether the travel distance and the trip duration should be taken into account.

None of these definitions provide answers or even hints to above questions. Furthermore, data sources and applications do not provide clear methodological guidelines for the examinations. Most SUMPs, and even the data provided by transport service providers and authorities rarely include the basis of comparison.

Accordingly, a possible definition of modal share is: *the modal share determines the performance ratio of available transport modes in a given area in a certain time period.*

2.3. Measuring and calculating the modal share

In the first half of the 20th century, the studies and applications have mainly examined the composition and changes of traffic and their connection with modal share, and the connection between motorized and public transport (Rooney, 2016). Later, in the 1950s and 60s modal share was used in a broader range: transport modes were examined in a typically bimodal perspective, namely public and private transport, although some surveys in the United States already included walking. In this era, the computational capacity caused difficulties in modelling (Michigan Department of Transportation, 1955). Due to the possibilities provided by the later technical innovations (GPS, traffic surveillance cameras, detectors, automatic passenger counting devices, etc.), the possibilities of examining traffic flows and various transport modes have expanded significantly. As the number of vehicles grew and the inspection possibilities of traffic flows improved, the range of applications also expanded—nowadays modal share is being examined more frequently, more widely and it can be determined by the measurement of several transport modes.

The capacity usage and modal share of transport modes can be determined by the use of several methods or a combination of them. 'Traditional' methods typically rely on passenger counting and measuring the distance travelled by passengers. Based on these measurements, the transport volume for each mode and vehicle can be determined or estimated, and thus the modal share can be calculated. Measuring methods can be divided into two groups: the data can be collected directly from passengers (e.g. surveys, interviews) or can be based on counting (vehicles, passengers, etc.). An additional possible classification:

- data collection through passenger interviews (travel recording):
  - *questioning passengers* (in person / by telephone / via the Internet): the subject is asked by the interviewer or the person surveying the characteristics of the journeys made and the transport modes used during the reference period (departure and destination point, travel time and distance);
  - *conducting a travel diary* (written / online): the respondent describes the trips made and the transport modes used during the reference period;
- tracking of passenger and vehicle traffic:
  - *on-board passenger counting* (manual / automatic): manual or automated passenger counting and on-board tracking the traffic on public transport modes;
  - vehicle *counting* (manual / automatic);
  - vehicle and mobile device *tracking* (automatic).

The modal share can be determined by modelling. Modelling can be accomplished by using decision models, e.g. different types of logit models to analyse unique, regional or mode-specific effects and features (see Astegiano et al., 2019 on the impact of new transport modes on modal share, the analysis of Meeder et al., 2017 on the effects of rough terrain, or the novel modelling approach to determine pedestrian modal share by Sanni and Abrantes, 2010). With the development of infocommunication technology, traffic modelling methods, and the expansion of computing capacity, macro-level traffic models will be suitable for mapping traffic flows and determining the real-time modal share if sufficiently up-to-date and detailed input data is available.

3. Methodology

The directions of research were set based on the research and observations made during the literature review. The most significant shortcomings and the inefficient and/or inaccurate methods of measuring and calculating modal share were identified. Obviously, during the research the searched keywords included the different name variations of modal share (e.g. mode share, mode choice, and modal split) combined with the different transport modes (public transport, private transport, walking, cycling, etc.), mobility concepts (autonomous mobility, shared mobility, active mobility, electromobility), measuring and calculating methods and methodologies to collect vehicle occupancy, walking and cycling traffic data.

Papers from the last ten years were collected to support the valuation of the current trends in measuring mobility, particularly the modal share. During the global level analysis of the topic scientific papers from all countries were accepted, but because of the considerable differences between the world's transport systems and local relevance,

papers studying European topics were preferred. Scientific papers and sources originated earlier were also used, since these earlier studies used similar definitions as it was presented by our study.

For case studies and the modal share data SUMPs were collected from across Europe from 2010 to the present. In the analysis of country-specific data and the collection methods the latest available statistical bulletins and publications were used. For the comparison of measuring methods and results the transport statistics of a number of selected European countries were used. Countries covered by the study were Hungary and its neighbouring countries, countries of Central Europe and other European Union member states with significant size in area and/or economy. The further analysis included transport modes' statistics available (measured) in at least ¼ of all countries. Hence, the evaluation includes the rail and road public transport, inland and maritime transport, aviation, local public transport, and individual road transport , but omits e.g. walking and cycling. Data collection also covered the applied units and the frequency of measuring.

Speaking about shortcomings, it can mean (i) the definitional inaccuracies in the terminology of the modal share topic, (ii) the absence of available or affordable technology or technology for a given specific task (e.g. device for counting pedestrians) that could be used to measure or calculate, (iii) methodological inaccuracy that can cause considerable discrepancy in results.

4. Results

The analysis of scientific sources and applications that are used for measuring and calculating the modal share showed that there are significant imbalances in the evaluation of different transport modes. These inbalances can have considerable impact on the results calculated with 'traditional' methods relying i.e. on measurments of transport service providers or authorities. Shortcomings in measurement technology and methodology also caused that in most cases papers measure only specific public and private transport modes (e.g. aviation, rail transport), leaving less 'measurable' (e.g. active mobility) modes out of the equation. For instance, though walking is an essential mode of transport that cannot be omitted when planning cities with a sustainable transport system, there is no fully developed measuring method used in practice that considers this mode. According to our investigation novel transport modes also need a proper framework to be fitted in, along with the more 'traditional' modes when measuring modal share.

4.1. Lack of reliable data

One of the primary problems is the lack of reliable data sources, regardless of the national, regional or local level of analysis. The European Union codified that the most important statistics for all transport modes at the EU level must be collected according to a common approach and standards that make transport modes comparable[§]. However, it does not effectively promote the collection of harmonized data since other indirect measuring and data collecting techniques are also permitted (see Article 5 of EU Regulation 2018/643). Referring to the balance of user needs and the burden on data providers, each country can provide data following its own measurement strategy based on less reliable and accurate methods.

4.2. Different measuring methods, methodological shortcomings

Data collection and regular reporting could be usefully complemented by detailed transport statistics in all member states in the EU. The rules applied depict the diversity of transport systems and allow to consider local peculiarities. However, the comparability of member states' transport systems' performance is not adequate. Table 1 summarizes the types of transport statistics in the selected European countries and the availability of transport modes' statistics, unit and frequency of measuring.

[§] *Regulation (EU) No. 2018/643 of the European Parliament and of the Council of 18 April 2018 on rail transport statistics* and the *Regulation (EU) No. 70/2012 of the European Parliament and of the Council of 18 January 2012 on statistical returns in respect of the carriage of goods by road Text with EEA relevance*.

Table 1. Measuring methods, frequencies and the modes measured in the selected countries of the European Union

Country	Measuring frequency	Type of data collection							Unit of measure
Austria	semi-annually	N.A.	‡	№	№	‡	№	№	pass
Croatia	weekly, monthly, quarterly	statistical surveys	‡	‡	‡	‡	№	№	pass, pass.km
Czech Republic	quarterly	statistical surveys	‡	‡	†	‡	†	№	pass, pass.km
Finland	monthly	collected direct from operators	‡	№	№	‡	№	№	pass, pass.km
France	monthly, quarterly	survey for companies, national transport and travel survey	‡	№	№	‡	‡	‡	pass, pass.km, vehicle.km
Germany	(at least annually)	N.A.	‡	‡	‡	‡	‡	№	pass, pass.km, vehicle.km, capacity.km
Hungary	quarterly	data collection and observations on a representative basis	‡	‡	‡	‡	‡	№	pass, pass.km
Iceland	annually	collected by Icelandic Transp. Authority	–*	№	№	‡	†	‡	pass, vehicles, usage rate
Italy	(at least annually)	N.A.	†	№	‡	‡	№	№	pass
Poland	(at least annually)	N.A.	‡	‡	‡	‡	‡	№	pass, pass.km, vehicle.km
Romania	quarterly	statistical surveys	‡	‡	‡	‡	№	№	pass, pass.km
Serbia	monthly / quarterly	questionnaire	‡	‡	№	‡	‡	№	pass, pass.km
Slovakia	(at least annually)	statistical surveys	‡	‡	‡	‡	№	№	pass, pass.km
Slovenia	depends: monthly / quarterly / annually	statistical surveys and administrative sources	‡	‡	‡	‡	‡**	‡	pass, pass.km
Spain	monthly	survey of companies in the transport sector	‡	‡	‡	‡	‡	№	pass, pass.km
Switzerland	(at least annually)	N.A.	‡	‡	‡	‡	‡	‡	pass, pass.km, vehicle.km, capacity.km
Sweden	(at least annually)	N.A.	‡	‡	‡	‡	‡	‡	pass, pass.km

Notation:
N.A. information not available
№ transport mode not measured / study not published online
† data is not available online or is unreliable
‡ data available online
(at least annually) apart from data no methodological guide is available, the statistical office publishes data on an annual basis
* no public rail network
** bus transport only

Sources: statistical offices of the selected countries

The frequency of data collection is satisfactory in each country, as the statistical offices and organizations publish their statistics on transport performance at least annually and quite often every quarter—this practice meets the requirements of the EU. However, the applied methods of data collection and the range of transport modes included in the statistics significantly differ from country to country. Aviation and rail traffic volume are surveyed in all countries, except for the country lacking a public rail system (Iceland). The performance of public bus transport, inland waterway and maritime transport services is also measured in about ⅔ of the countries. Urban public transport is examined in about half of the countries, and the performance of individual road transport is examined in only one-fifth of them. Typical urban transport modes (e.g. cycling, walking) are omitted from the national statistics, the share of soft mobility modes and walking are only measured in Switzerland.

Based on the applied data collection methods, countries can be divided into three categories:

- organizational approach, collecting data from transport service providers, transport authorities, service integrators;
- passenger side approach, creating statistics using travel surveys (diaries) and passenger interviews;
- mixed approach, using a mixture of methods (e.g. service data collection and passenger surveys).

The information about how data can be collected, was unavailable in ⅓ of the countries. Statistics are usually based on the number of passengers carried, but in ¾ of the cases, the performance of the given transport mode was also measured in passenger-kilometres. For some countries, the statistics are supplemented with an examination of some particular operating characteristics, such as vehicle- or capacity-kilometres.

4.3. Calculating modal share

Among all the listed shortcomings of measuring methodology, the issue of multimodal and intermodal trips must be emphasised and highlighted. The methodology of measuring performance is highly dependent on how the trip sections and the related transport modes are handled and valued. For example, it is an important methodological choice whether the access and egress trips travelled by foot should be attached to the independent trip sections of pedestrians,

should be considered as an independent section of the journey, or should be omitted despite the fact that walking can account for a significant portion of the total travel time due to its slower speed.

5. Conclusion

Modal share is a well known and often used indicator of transport systems and processes. Recent studies tend to focus on the modelling decisions instead of the questions of the valuation and the measurement of modal share. However, measuring and analysing modal share is still relavant since technological developments can support the more accurate and complete measurement of the use of transport modes. The main result of this study is the comprehensive research and the evaluation of studies aiming to clarify the concept of modal share in the light of mobility trends of current times. Our paper highlights the major shortcomings of the current pratice using the indicator of modal share: lack of standard terminology, different measurement methods with major transport modes ommited, unclear influential factors of the modal share, and the need of a clear framework and/or model.

The main contribution of this research is a clear framework and terminology for the topic of modal share that also includes the possible methods for measuring and calculating in practice. According to the new definition created *the modal share determines the performance ratio of available transport modes in a given area and a certain time period*. A key finding of the study is that the option for novel transport modes has to be included in the model, and the importance of measuring and taking walking into account cannot be neglected.

Future works include a detailed review, methodological development (measurement and calculation methods), and modelling of walking and novel transport modes as these modes form the urban landscape.

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