# Use of Time: Theories and Application in the Age of Digitalisation

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# Abstract

The world is changing. Digitalisation affects every aspect of everyday life, as well as how we spend our time. Some activities are shortened, others need more time, certain activities change heavily, while a few disappear altogether.

But how is this measured? How can a day, a week, a year, or even the whole lifespan of a person be analysed? There are different theories from different disciplines to answer questions about the use of time.

This work is concerned with preparing these theories, contrasting and comparing them with each other. The main issue is which theory is suitable for answering which questions. These questions relate above all to the aforementioned effects of digitalisation.

Thus, this paper consists of three different parts:

1) Of the elaboration of the various theories in which they are described.

2) Of the comparison, in which basic assumptions and approaches are brought into relation with one another and commonalities and differences of the various theories are examined in relation to questions to which they can provide answers.

3) And finally, of the application of these questions to the already occurring and future possible changes in the use of time by digitalisation. Existing work on the effects of digitalisation on the respective field will be presented and reflected upon.

# Zusammenfassung

Die Welt verändert sich. Die Digitalisierung beeinflusst jeden Aspekt des täglichen Lebens, sowie auch wie wir unsere Zeit verbringen. Manche Aktivitäten verkürzen sich, andere benötigen mehr Zeit, bestimme Aktivitäten verändern sich stark, während einige völlig verschwinden.

Doch wie wird das gemessen? Wie kann ein Tag, eine Woche, oder sogar das ganze Leben einer Person analysiert werden? Es gibt verschiedene Theorien aus unterschiedlichen Disziplinen, um Fragen über die Zeitnutzung zu beantworten.

Diese Arbeit beschäftigt sich mit der Aufbereitung dieser Theorien, sie einander gegenüberzustellen und miteinander zu vergleichen. Das Hauptthema ist, welche Theorie welche Fragen beantworten kann. Diese Fragen beziehen sich vor allem auf die oben genannten Effekte der Digitalisierung.

Das Dokument besteht aus drei Teilen:

1) Aus der Ausarbeitung der verschiedenen Theorien, in denen sie beschrieben werden.

2) Aus dem Vergleich, in dem grundlegende Annahmen und Ansätze miteinander in Beziehung gesetzt werden und Gemeinsamkeiten und Unterschieden der verschiedenen Theorien untersucht werden, in Bezug auf die Fragen, auf die sie Antworten geben können.

3) Und schlussendlich aus der Anwendung dieser Fragen auf die bereits auftretenden und möglichen zukünftigen Veränderungen der Zeitnutzung aufgrund der Digitalisierung. Bestehende Arbeiten zu den Auswirkungen der Digitalisierung auf das jeweilige Feld werden vorgestellt und reflektiert.

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# List of Abbreviations

| | |
|---|---|
| ATUS | American Time Use Survey |
| CARLA | Combinatorial Algorithm for Rescheduling Lists of Activities |
| CTUR | Centre for Time Use Research |
| eIJUR | electronic International Journal of Time Use Research |
| ESM | Experiential Sampling Method |
| GIS | Geographic Information System |
| IoT | Internet of Things |
| LBS | Location-Based Services |
| PESASP | Program Evaluating the Set of Alternative Sample Paths |
| STARCHILD | Simulation of Travel/Activity Responses to Complex Household Interactive Logistic Decisions |
| TUS | Eurostat Time Use Survey |

# 1. Introduction

*“How should I spend my time?”*

*“Is this activity worth my time?”*

*“How can I save time doing necessary tasks I do not like to have more time for things I do like?”*

These and other questions of a similar subject are subconsciously always in our heads. This resource called time is probably the most valuable possession of a human being, and still, no one knows exactly how much is still left of their lifetime. Therefore, it is no surprise that we try to optimize our time to the fullest.

Understandably, this topic has also been picked up by researchers all around the globe. There are many fields of studies, ranging from sociology over economics to even geography, trying to measure everyday time use in different, unique ways, quantitatively and qualitatively.

Another big part of our lives is the rapid change our society is undergoing at the moment called the fourth industrialization. Every part of our daily life is affected by this digitalisation. As the tools we have at hand transform, so does our behaviour as well as our use of time.

This thesis combines these two big parts of our lives and tries to show, how different questions risen by the digitalisation can be examined using time theories. To reach this goal, this paper comprises three parts.

The second chapter introduces the reader to different fields of research about time use. Each theory has a subchapter that introduces the reader to its goals and underlying concepts and a subchapter showing different use cases on how these theories are being utilized in today’s research.

The third part then compares these different theories with the aid of the use cases discussed in the first chapter.

The fourth chapter is about how these time theories can be applied to measure and analyse changes triggered by the digitalisation.

Lastly, the results will be discussed and reflected upon.

# 2. Theories

## 2.1. Time Use Theory

The most prominent concept about time usage is the time use theory. There are a lot of local and global research centres (e.g. the Centre for Time Use Research (CTUR) of the University of Oxford or the globally active electronic International Journal of Time Use Research (eIJTUR)). There are even governmental or government-funded organisations and surveys such as the American Time Use Survey (ATUS) by the United States Department of Labor or the Eurostat Time Use Survey (TUS) by the European Commission.

### 2.1.1 The Theory

#### 2.1.1.1 Goal

This approach is mainly focused on the collection of data about executed activities, including influencing variables like the location where the activity took place, the companionship in which the activity was carried out, or what other secondary activities were executed at the same time by the same individual (Ås, 1978). All these aspects will be explained in more detail below.

This data is then used for various implementation that are mostly aimed at measuring living conditions of different groups of society up to a society as whole. Some examples will be given in chapter 2.2.

#### 2.1.1.2 Concepts

*Activity*

The main term of this theory is the “activity”. It is crucial for this approach to define the aspects of an activity to distinguish different kinds of activities and categorise them. Dagfinn Ås (1978, p. 126) explained it as such that “reality at hand is a stream of behaviour” and an activity is a behaviour unit with a clear beginning and end to it. An example for an activity is “Going to the theatre with friends”.

Each of these activities can be broken down into smaller, more detailed units. This might be “walking to the theatre” and “looking for a seat in the theatre hall”. The smallest possible unit Ås calls “act”. An act “is an interaction of humans and their environment” (Ås, 1978, p. 126) and cannot be interpreted in a meaningful way unless some information about the behaving individual and the immediate environment is given. Examples could be the act of “walking” or “chewing”. The scientist can choose which level of detail is most useful to his research. However, there is no use for such a high level of detail of an activity where the act’s purpose is no longer evident (Ås, 1978).

On the contrary, the reverse technique can be used to combine acts or smaller activities to bigger ones. You could, for example, combine the activities “going for a walk with a friend” and

“eating with a friend” to “meeting with a friend”. However, this also cannot be taken to an arbitrary level of generality as the activity records start to lose their sense when no details are given. A researcher cannot do anything with “I lived a day”. Usually, a day written down in a time diary consists of about 30 activities (Ås, 1978).

Another problem of tracking people’s daily activities is that they are not always subsequently taking place. Activities can interact with each other in different ways. One activity can get interrupted by another one, like “Eating alone” and then a friend comes by to chat. Another possibility is that an activity starts while another one is still carrying on, e.g. when you keep eating while you talk to your friend. They can also overlap, when the friend starts eating too and the activity “Eating alone” changes to the activity “Eating with a friend”. They can also just happen simultaneously, like “Eating” while “Listening to music. The more detailed the records are the more frequent are such occurrences. Again, it depends on the research goal how such cases are handled. Most of the time, it is easy to distinguish the main activity from secondary ones.

The last point to be discussed is the verbal component that many activities include (e.g. talking). It plays an important part in our behaviour, but the content is often irrelevant for classifying the activity itself. This is why it can be ignored for most of these studies (Ås, 1978).

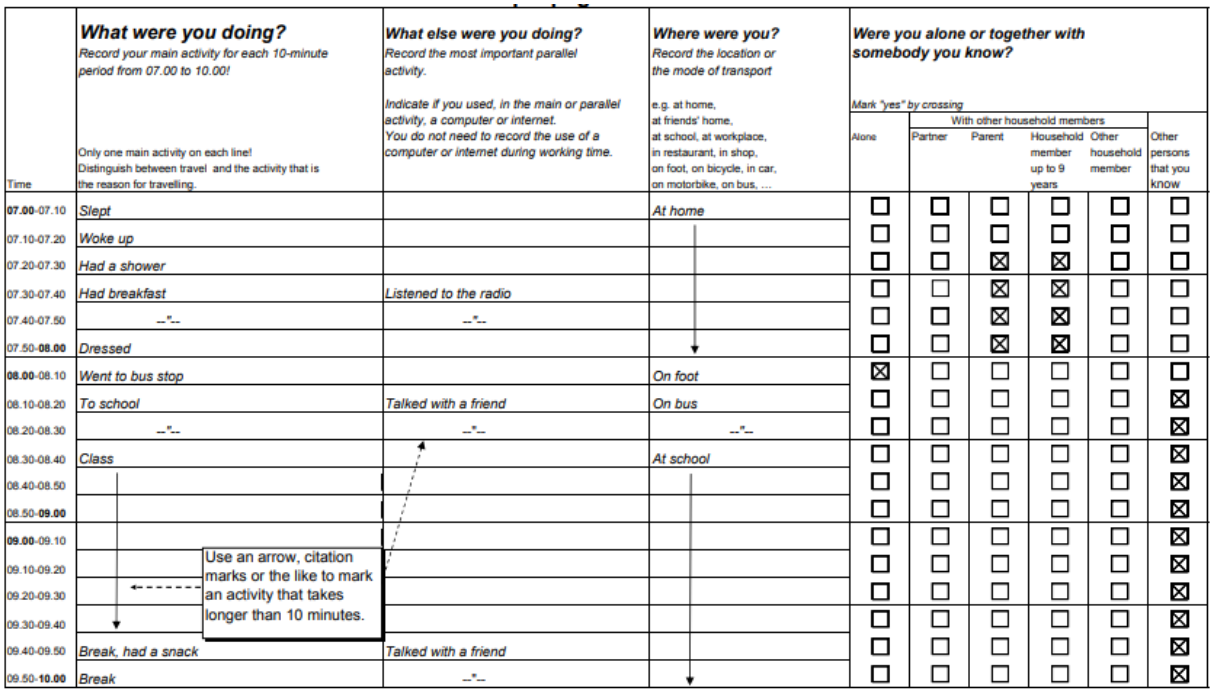
*Data Collection*

The Time Use Theory measures the time use of a test group over a certain period. To accomplish that, tests subjects report their daily activities to the researchers. There are different methods to do this, all with their pros and cons.

Time diaries are the most used method of collecting time use data. Test subjects are asked to record their activities in a diary over the course of a certain period, mainly 24 hours. Besides, they should list how much time each activity consumed in either an open-ended question or, rarer, in time slots of (e.g.) 5 minutes. Furthermore, it may be asked with whom, for whom and/or where the activity took place, if another activity was executed at the same time (this will be discussed further down) or how the subject felt during the activity, depending on the research purpose. (National Research Council, 2000). An example is provided in figure 2.1.

Time diaries can either be filled out on the respective day, so-called “leave-behind diaries”, or retrospectively, i.e. after the designated day with the help of a research affiliate.

Leave-behind diaries are usually more expensive as they require an orientation interview beforehand and, if need be, an interview afterwards to clarify answers or fill in missing information.




2.1: Example for a Time Diary, Source: Eurostat, 2009

Retrospective diaries only require one phone call after the respective diary day and are therefore cheaper. However, they depend on the ability of the participant to recall their use of time the prior day (as the time diary is mostly filled in the day after the designated day) (National Research Council, 2000).

Stylized questions are the cheapest way of measuring time use. They can be used complementary to a time diary for activities that may not be captured by a time diary, like irregular, rare activities (e.g. holidays), activities that participants are unwilling to report (e.g. sexual activities), or secondary activities that are not recorded in the diary (e.g. passive child care). They may also be used as stand-alone measurement. Examples for stylized questions are: “How much time do you spend commuting to work per week?” or “How often do you watch TV?”. The questions can be open-ended where the participant fills in the approximate number of hours doing the activity, or there can be a range of answers for the subject to choose from, like “never”, “once a week” or “every day” (National Research Council, 2000).

As may have been noticed, this method of measurement is imprecise to a certain extent. Participants may exaggerate time used doing socially “good” activities, like doing sports, and understate socially “bad” activities, like watching TV. Another reason for errors is simply the capacity for remembering how often and how long a test subject executed an activity depending on how often and how regularly it takes place. For example, the time of commuting is much more present in the participant’s mind than the time used to phoning as it varies greatly each day or week. Furthermore, the participant may not know how to report simultaneous activities, like watching TV while doing other things. The results can vary greatly depending on

the decision if the secondary activity needs to be included in the amount or not (National Research Council, 2000).

The first form to follow is a modification of a form used in the Sloan Study of Youth and Social Development (Csikszentmihalyi & Schneider, 2000). The second was used in the 500 Family Study (Schneider & Waite, 2005).

Date _____ Time beeped _____ a.m./p.m. Time you answered _____ a.m./p.m.

**As you were beeped . . . (be specific)**
Where were you?

What were you thinking about?

What was the main thing you were doing?

What else were you doing?

| | *Not at all* | | | | *Very much* |
|---|---|---|---|---|---|
| Did you enjoy what you were doing? | 1 | 2 | 3 | 4 | 5 |
| How well were you concentrating? | 1 | 2 | 3 | 4 | 5 |
| Did you feel good about yourself? | 1 | 2 | 3 | 4 | 5 |
| Were you learning anything or getting better at something? | 1 | 2 | 3 | 4 | 5 |
| Did you have some choice in picking this activity? | 1 | 2 | 3 | 4 | 5 |

**Describe your mood as you were beeped:**

| | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | |
|---|---|---|---|---|---|---|---|---|
| Happy | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Sad |
| Passive | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Active |
| Ashamed | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Proud |
| Worried | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Relaxed |
| Weak | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Strong |
| Lonely | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Sociable |
| Excited | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Bored |
| Angry | 3 | 2 | 1 | 0 | 1 | 2 | 3 | Friendly |

**Who were you with? (Check all that apply)**

( ) alone
( ) mother
( ) father
( ) sister(s) or brother(s)
( ) other relatives
( ) others (who?_____)
( ) teacher(s)
( ) classmates, peers
( ) other adult (coach, etc.)
( ) friend(s) How many?
___ females ___ males

2.2: An Example for an Experience Sampling Form, Source: Hektner, Schmidt & Csikszentmihalyi (2007)

Another stand-alone method to collect time use data is the Experiential Sampling Method (ESM). Usually, the participant gets a pager or similar that beeps at random times during the day. Then, they are asked to fill in a form to record when they got beeped, what they were doing, where they were, who they were with and/or what their thoughts and feelings were depending on the research purpose. As the questions are open-ended, as in time diaries, the answers are more specific and detailed than in stylized questions. These answers are therefore harder to classify but can also be a chance for the researcher to alter the classifications to fit the research purpose (National Research Council, 2000). An example is shown in figure 2.2.

The advantage of interrupting the participant as they are doing the activity is that there is no timespan between the activity and the report about it, so the possibility of an error of

inaccuracy regarding intentional or unintentional false statements is minimized, as the participant has no time to forget or even alter their behaviour to a socially more accepted activity.

The disadvantages are that this measuring method is very expensive and may not be used for a larger sample. Moreover, the pager is much more intruding into the daily life and there may be a selection bias of who participates in such a survey. Lastly, some activities might be missed as the survey is, firstly, not laid-out to measure a whole day worth of activities and, secondly, participants may have inhibitions on taking the pager with them at any time, as they might not want to be disturbed during some activities. Some surveys showed that there are significantly less activities recorded outside the home with this method than there are with the time diary method (National Research Council, 2000).

The last method to collect time use data is a third party that observes the participant. This could be an independent third person, a colleague, a family member, or even cameras and other gadgets. Sometimes it can also be useful to observe a participant in an observational room (e.g. observing the use of time of children).

The advantage of an objective observer is the accuracy of the data. The problems, however, are that, firstly, this method is very expensive and intrusive and, secondly, that there needs to be consent about observing the participant, which means that they are aware of it and may behave differently than in a non-observing environment (National Research Council, 2000).

*Categorisation of Time/Activity Groups*

After the collection of data, they need to be analysed and categorised. The most interesting part for this paper is the categorisation of activities. The two main categories usually are work and free time but there are many subcategories to further differentiate between activities. There are different approaches and some uncertainties and discussions about how to categorise certain aspects of activities.

Ås (1978) proposes four kinds of time: necessary time for basic physiological needs like eating and sleeping, contracted time for time spent at the workplace, committed time for activities one has committed to with earlier actions (e.g. housework after buying a house, childcare after birth), and free time for all the activities done for leisure. Javeau (1970) and Govaerts (1969) took the same approach.

A different categorisation chose the OECD (2009) in their report “Gesellschaft auf einen Blick”. They worked with the categories “Freizeit” (free time), “Erwerbsarbeit” (gainful employment), “erwerbslose Arbeit” (voluntary work), “persönliche Pflege” (personal needs) and “sonstige Zeitnutzung” (miscellaneous time use).

Szalai (1972) used a more detailed approach in his leading work “The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries”. The categories are “work”, “housework”, “child care”, “shopping”, “personal needs”, “education”, “organisational activity”,

“entertainment” (e.g. movies), “active leisure” (e.g. sports) and “passive leisure” (e.g. reading books).

All these approaches as well as variations of them or even totally new categorical choices are accurate depending on the data set and the questions the researcher wants to answer. Naturally these categories are divided further to get a certain level of detail to work with.

Some categorisation however needs to be discussed further.

Firstly, where does time to travel belong? Is it accounted towards the activity it is done for or is it a separate category? As you can see, all the aforementioned examples classified travel to the corresponding activity. However, a guidance by Eurostat (2009) to harmonise time use surveys introduced an additional category only for measuring travel except for physical exercise like jogging and travel done for work (e.g. business trips). They also asked participants to specify their travel means. Ås (1978) also argued that travel could be seen as committed time as it is a consequence of a plan to carry out an activity later or have already carried out. Here again is the question if the researcher needs this level of detail as it further increases the workload for both participant and analyst.

Secondly, it is not clearly defined if education is considered to be free time or work. This is important as these studies often analyse the use of time regarding these two aspects as parent categories. Most of the surveys consider education as free time (e.g. Szalai, 1972) as it is not paid work and thus does not fall into the broad “work” category. Nonetheless, Ås (1978) argues that the time spent in regular schools should count to the time of work. Adult education, however, should count to leisure time as one can freely choose whether to participate in further education.

The last unclarity concerns childcare. While every other survey categorises it under free time, Ås (1978) counts taking care of small children as committed time as they require certain attention from their parents. This can influence the measured free time to a high degree depending on the living circumstances of the participants.

### 2.1.2 The Application

As the principles of time use are now laid out, this chapter shows different applications on how to utilize the time use theory.

One possible application is the examination of average time spent working, either at the workplace or at home. The ATUS 2017, for example, states percentages of the employed American populace working on weekdays in comparison to weekend days, and examines, furthermore, worked hours on an average workday split into time worked at the workplace versus at home (Bureau of Labor Statistics, 2017).

Another application is the determination of time at the workplace in comparison to free time and non-paid work (National Research Council, 2000). An example would be the survey undertaken by the OECD. This study compared the overall free time and its time allocation

over all the OECD nations for which data was available. It was part of a larger report that analysed different social indicators, developed in the 1980s, to measure living and working conditions (OECD, 2009).

As the children are the future of every nation, a time use survey can also determine the time spent with childcare. The ATUS 2017 compares time spent with children under the age of six to the time spent with children older than six years (Bureau of Labor Statistics, 2017).

One can also measure the time use of the children themselves and the influence of their parents (Fisher et al., 2015, Bianchi & Robinson, 1997), or contrary time use of elderly after retirement (Gauthier & Smeeding, 2010), or compare the time use of the employed populace before and after retirement (Bonke, 2015).

Regarding the issue with the categorisation of travel, there are some papers that analyse the utility of time during travel. Instead of dismissing it as unproductive time, Lyons, Jain & Holley (2007) studied what people do with their idle time during commuting.

Basner et al. (2007) used data of the ATUS to analyse waking activities of people whose sleeping patterns are below or above average. Since too much as well as too little sleep is seen as a factor to a higher risk of mortality, morbidity and overall sickness, they tested if these risks are not the result of their sleeping patterns but of these individuals' activity patterns during the day.

Another possible use case regarding health concerns examined Smith, Ng & Popkin (2013). They analysed the trends of preparing food at home versus eating out in US households with the help of time use studies from 1965 - 1966 to 2007 – 2008.

Time use studies can also be useful for energy consumption studies as Widén, Lundh, Vassileva, Dahlquist, Ellegård and Wäckelgård (2009) show. To quantify the end-use of energy in detail a disproportionately high number of measurement devises would be needed. Therefore, it is much more efficient to use time diaries to determine the energy's end use.

Torriti (2017) also used time use data to study the energy consumption of everyday life. He combined them with the practice theory (see chapter 7.1)

## 2.2 Time-Geography

Another theory about the use of time but from a totally different angle, namely, as the name of the theory suggests, a geographical view point is the "Time-Geography Theory" constituted by Torsten Hägerstrand (1970) as he was bothered by the fact that human behaviour had mostly been analysed in a macro-level without considering "[…] the assumed social organisation and technology that exist at the micro-level from which the individual tries to handle his situation" (Hägerstrand, 1970, p. 8). In his work, he criticised that most studies handled human migration the same as trading goods or money as soon as data is aggregated. The theory, however, does not aim to have a look at every person individually but consider the fact that people are indeed individuals (Hägerstrand, 1970).

## 2.2.1 The Theory

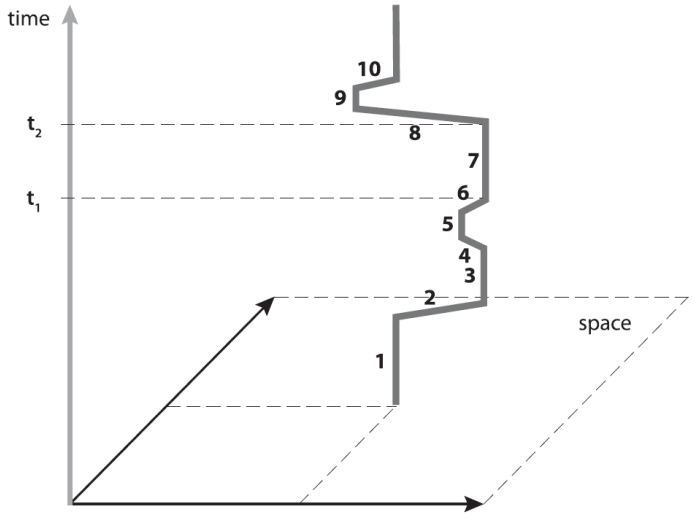
### 2.2.1.1 Goal

The main proposal of this theory is to measure one's life in a life path beginning with their birth and ending with their death. This life path can be shown in a three- or two-dimensional time-space-diagram "if we agree to collapse three-dimensional space into a two-dimensional plain or even a one-dimensional island, and use perpendicular direction to represent time" (Hägerstrand, 1970, p. 10).

### 2.2.1.2 Concepts

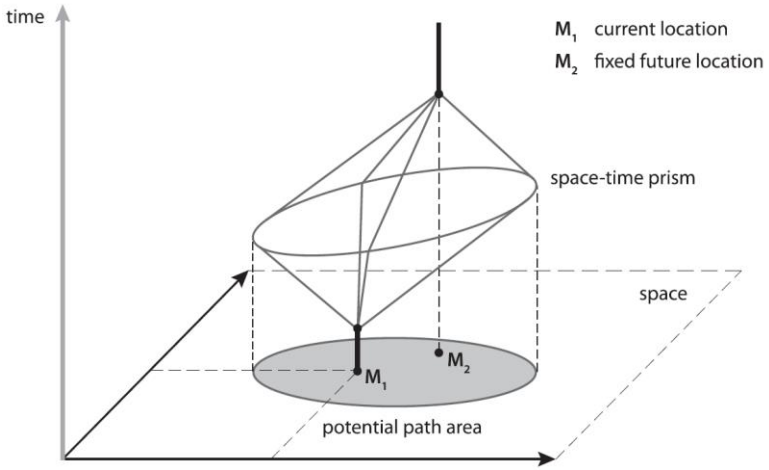
*Life Path*

Every person's life can be recorded as a life path in a three- or two-dimensional time-space diagram as mentioned above. This life path can be divided into smaller elements of life (such as years or days), whereas days are the most frequent used time frame and can be visualized as in figure 3.1.




2.3: Visualization of a day path
1) home, 2) travel to work, 3) work, 4) travel to lunch, 5) lunch, 6) travel back to work, 7) work, 8) travel to shop, 9) grocery shopping, 10) travel home, Source: Šveda & Madajová ( 2012)

In regard of the constraints in a human life (discussed below), the maximum of daily travel shown in a time-space diagram looks like a prism, as it is considered that every person has some sort of "home base" where they return back to (Hägerstrand, 1970). Such prisms are shown in figure 3.2.




2.4: Space-time prism as maximum path, Source: Šveda & Madajová (2012)

These prisms are restricted by space-time walls, outside of which an individual cannot possibly appear. Each stay they take reduces the remaining prism depending on the length of the stay. A standard day path in western society contains around eight hours of work with remaining prisms for leisure activities before work, during lunch, and in the evening after work (Hägerstrand, 1970).

*Activity*

The definition made in the previous chapter holds for this theory too.

*Constraints*

A human is not totally free in his doings. The society and its laws and morals, his social environment and its expectations, his own mindset of right and wrong and his physical body and its limitations all put constraints on him. Hägerstrand (1970) found three categories of constraints: “capability constraints”, “coupling constraints” and “authority constraints”.

**Capability Constraints**: These constraints are the limitations of an individual’s body meaning the biological boundaries (e.g. sleep) (Hägerstrand, 1970) as well as the ability or the lack of it to use certain tools (e.g. being able to drive or the maximum speed of the car) (Šveda & Madajová, 2012).

**Coupling Constraints**: Coupling constraints need to be considered when there is some sort of social interaction involved in the activity the individual wants to execute. “These define where, when and for how long” (Hägerstrand, 1970, p. 14) an individual must cooperate with other individuals or use tools and materials to fulfil his needs (e.g. opening hours of a shop) (Hägerstrand, 1970). It also considers that individuals need to make decisions about activities and transport means as they cannot be everywhere with everyone at the same time (Šveda & Madajová, 2012).

**Authority Constraints**: These constraints are legal, social or moral rules of the environment the individual lives in or of the individuals themselves. These can be restrictions

or prohibitions of certain activities (e.g. illegal activities) as well as physical boundaries (e.g. private estate where admittance is prohibited) (Šveda & Madajová, 2012).

*Tubes*

Hägerstrand (1970) defines three types of tubes around each human being. These tubes are specific capability constraints that are worth mentioning.

The first tube, the “inner tube” is the space around an individual that he can reach with his arms without leaving his current position.

The second tube is the space as far as the voice and the eyesight of an individual reaches. It is the communication range of a human being. This tube is greatly influenced by digital means of communication. As Hägerstrand wrote his paper before the digitalisation, he mentions the probable influence of “telecommunications” in the future, but his theory lacks the explanation of how to deal with i.e. the Internet. How to connect the Time-Geography Theory with digitalisation will be discussed later in this chapter.

The third tube is the distance in which an individual can travel if it is assumed that they must return to a home base in regular intervals to get rest and keep personal belongings. This tube was influenced heavily by the development of faster transport means like cars, trains and planes as people now can cover much more distance in a fixed period of time (Hägerstrand, 1970).

*Stations*

Stations are all the places where individuals carry out their activities. They can commute between and communicate and interact with them (Šveda & Madajová, 2012).

*Bundles*

Bundles are a direct effect of the coupling constraints. They happen when two or more individuals have to work together on an activity. They can either be at the same station (e.g. a meeting at work) or communicate with each other via digital means (e.g. phoning).

*Control Area/Domain*

Domains are the physical equivalents of authority constraints. They “refer to a time-space entity within which things and events are under the control of a given individual or a given group” (Hägerstrand, 1970, p. 16). These areas can occur naturally, many animals have them, as well as be legally enforced (e.g. countries, factories). They are meant to protect resources or the efficient arrangement of bundles.

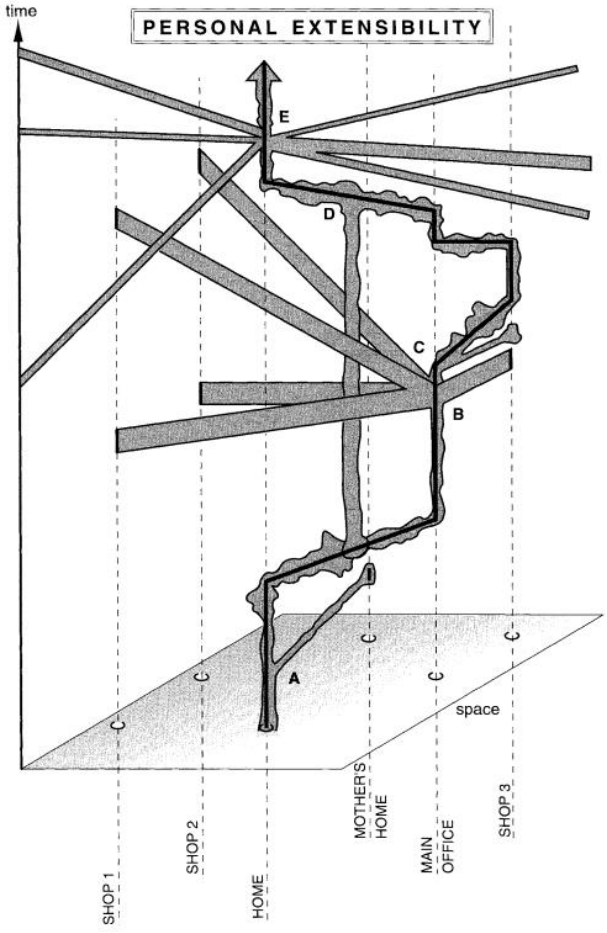
In the time-space diagram these domains appear as cylinders that are either not at all or only with special permission accessible.

There are different kinds of areas. Some are protected only by power or custom (e.g. sandcastle), others have, as mentioned, a legal status (e.g. real estate). There are temporary control areas (e.g. a theatre seat) as well as long-term, almost eternal, domains like countries or universities.

Regarding the hierarchy of these domains, there is obviously a big difference between a country and a sandcastle. The individual or the group who has the power in a superior domain can use this advantage to control subordinate domains and dictate their constraints or the removal of them even against their will. If they are on a similar hierarchy level, they can influence each other by trading, negotiating or even warfare (Hägerstrand, 1970).

#### 2.2.1.3 Adaptions due to Digitalisation

With the changes the digitalisation has brought and still brings, it gets more and more complex to describe the human life path by only physical means. A secondary space, the virtual space, has been created, where people can participate in activities either in this virtual space directly or in activities in the physical space remotely. This so-called cyberspace can circumvent the physical constraints defined by the original time-geography theory, which must be modified to take the virtual space into account (Yu & Shaw, 2008).



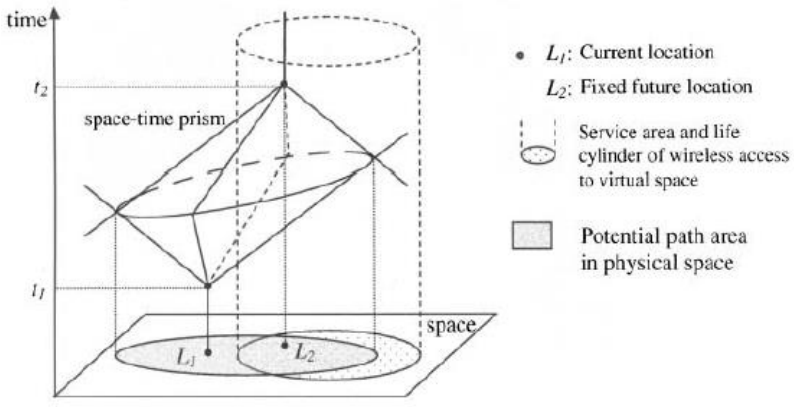

2.5: Time-space extensibility diagram
The bolt line is the day path, the shaded area around it is the extended second tube of Hägerstrand (1970), A) Call to mother, B) E-mails to shop managers, the day managers receive it immediately, whereas the night managers of shop 1 and 2 receive it in the evening, C) phone call with shop 3, D) Seen car accident in the morning lets them drive more careful at the same intersection, E) watching news on television, source: Adams (1995)

Different methods have been proposed to address this problem:

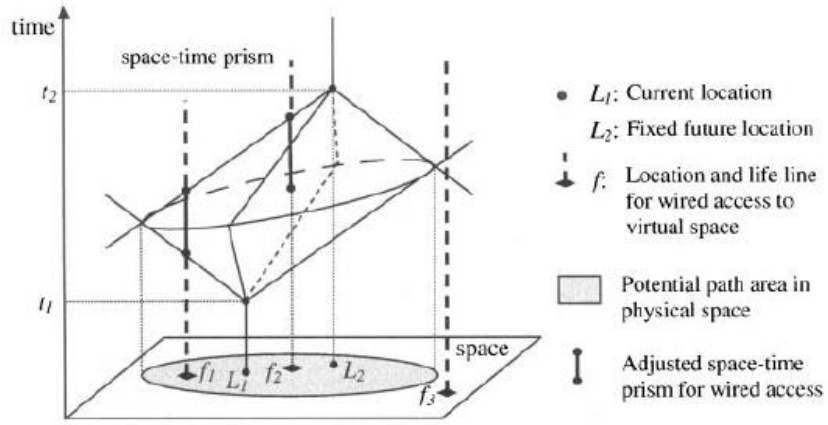
One proposition was made by Adams (1995). He implemented the second tube (communication) into the time-space diagram in the form of a shaded area that emanates from the main path, calling it the “time-space extensibility diagram”.

An example is shown in figure 3.3. This shaded area shows the involvement of an individual in distant areas and events. Adams (1995) lists to types of involvement, the controlling involvement where an individual influences the happening (e.g. a CEO ordering the closing of a factory, where hundreds of people lose their jobs), and the experiencing involvement, where an individual experiences the happening without actually being able to influence it (e.g. watching news about a natural disaster at the other side of the world). With this representation, it is possible to map bundles in the virtual world like everyone who watches the same channel on television.

Yu & Shaw (2008) extended the time-geography theory in another way. First, certain spatial constraints are alleviated through the virtual space, as one does not necessarily need to be at the same physical place as the activity they want to participate in if they can participate in it through telecommunication means. However, as a connection to the virtual world must be established, which is not (yet) possible from anywhere, new constraints are being created. An individual needs access points in the physical space to connect to the virtual space. The availability of these influence the behaviour of individuals since they have different sets of potential activities to choose from depending on whether or not the virtual space is available to them at the moment. Furthermore, Yu & Shaw (2008) distinguish two kinds of access points, the wired and the wireless access. To use the wired access (e.g. fixed phone lines, wired Internet ports), a person needs to be at the exact spot of the access point to be able to use it. In the space-time diagram, these points are represented by vertical lines. If an individual uses a wireless access point, they have more freedom in choosing a location to access the virtual space, as the connection is available in a broader region. These wireless access points are represented as cylinders in the space-time diagram. Examples of both wired and wireless access points are shown in figures 3.4 and 3.5.



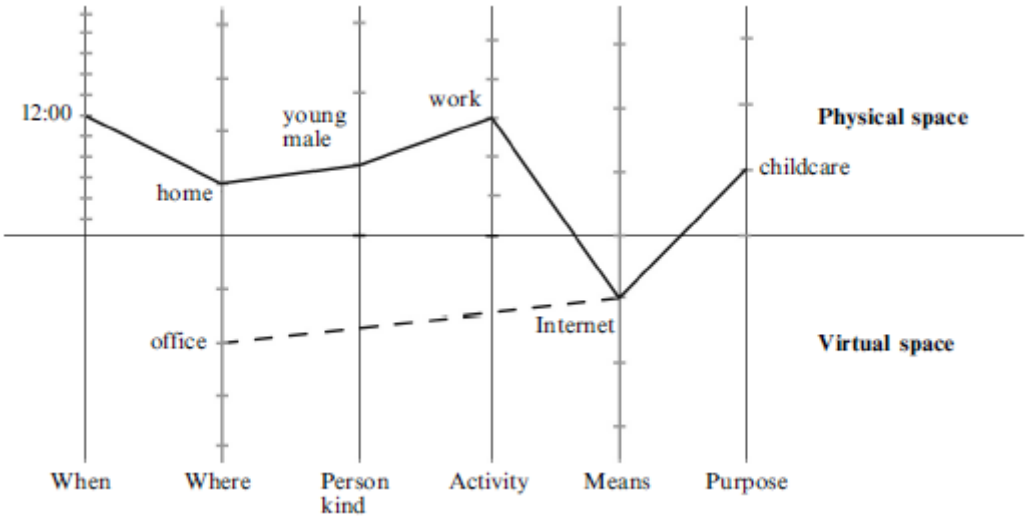

2.6: Example for the representation of a wireless access point in a space-time diagram, Source: Yu & Shaw (2008)



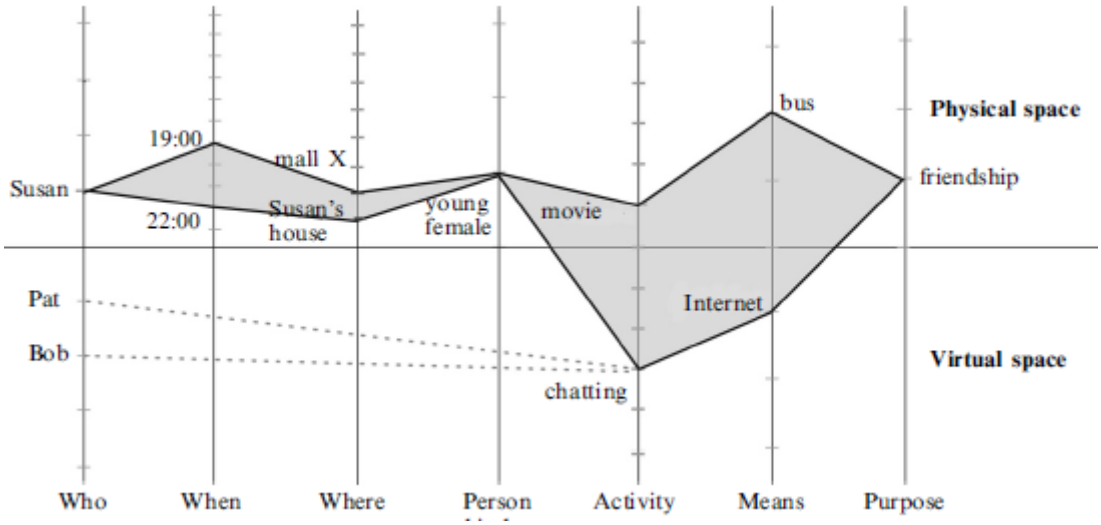

2.7: Example for the representation of a wired access point in a space-time diagram, whereas f2 does not have 24h service, Source: Yu & Shaw (2008)

According to Yu and Shaw (2008), there are four different kinds of communication, namely the cross products of two spatial (physical or tele-presence) and two temporal (synchronous or asynchronous) constraints. Examples for each case would be face-to-face conversation for synchronous physical presence, Post-it notes for asynchronous physical presence, telephone for synchronous tele-presence and e-mail for asynchronous tele-presence. Whereas the individuals need to be at the same place when communicating via physical means, either at the same time or after one another in the correct order (as only the first individual (initiator) can communicate with the second (receiver) and not vice versa if asynchronous means are chosen), individuals who communicate via tele-presence need only to have access to telecommunication means at the right time. This means they can communicate with each other without their paths ever crossing. So, the necessity to communicate with others impose different constraints on oneself depending on the chosen communication method, and telecommunication systems open new forms of interacting with each other that themselves entail new constraints on the communicators.

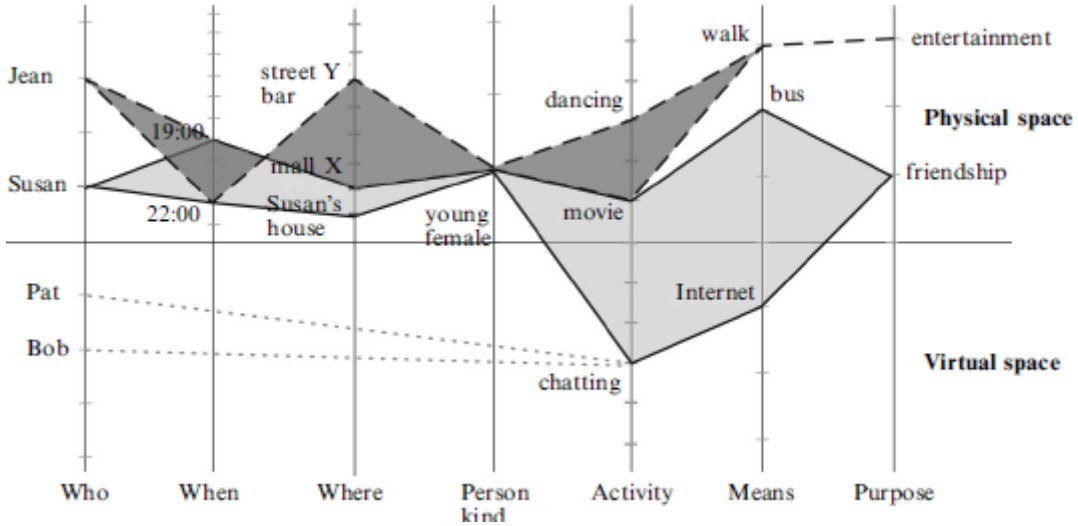
The third alteration of the space-time diagram comes from Couclelis (2009). The changes proposed in this paper are the most extensive of these three. The three-dimensional space-time diagram should be extended by four more dimensions, the formal, the constitutive, the agentive, and the telic dimension, and hence the time-space diagram becomes a multi-dimensional space. These four additional dimensions are meant to give more purpose to each activity. The formal dimension specifies the kind of person (e.g. sex, age, occupation) that is observed. The constitutive level lists the activity that is executed at the moment (e.g. movie, work). The agentive level is for tracking the means with which the activity is accessed or executed (e.g. bus, Internet). The last dimension, the telic level, shows the purpose of the activity (e.g. friendship, entertainment). These levels also work for other research purposes and the object of interest does not always have to be a human. All the dimensions are presented in a schematic data model, an “attribute sheet”. The sheets in figures 3.6, 3.7 and 3.8 show a human centred view (Couclelis, 2009).




2.8: A point in time shown as proposed by Couclelis (2009), Source: Couclelis (2009)




2.9: A time path of an evening of a single person, Source: Couclelis (2009)




2.10: Illustration of a time path of an evening of multiple people, Source: Couclelis (2009)

### 2.2.2 The Application

As the time-geography theory is, as the name says, a geographical interpretation of the use of human time, the applications are connected to human travel behaviour to a certain extent. As the visual representation in geographical research is of uttermost importance, most of the scientists work with so-called Geographical Information Systems (GIS) to visualize their gathered data. However, as most of the research only needs spatial variables, new ways were needed to visualize time-geography data with spatial and temporal variables (Yu & Shaw, 2008). Such solutions were developed by, e.g., Kwan (2000) and Yu & Shaw (2008). GPS is another useful tool of the modern age to track someone's movement throughout time and space. However, there is a risk that the actual purpose of time-geography, to keep the individuals to be examined individually, gets lost as this technology does not register the executed activity but only the location where it was executed (Ellegård, 2018).

The first subject which comes to mind when thinking about possible applications of time-geography is the development and planning of regional and urban transportation systems. Hägerstrand and Öberg (1970, as cited in Ellegård, 2018) tested, for example, the distance and time needed for people in different regions (urban, suburban, rural) to reach certain services.

As constraints are a crucial part in time-geography, it is no wonder that one field of application is the accessibility level of the transportation network. This means examining the usefulness of the system in regards of "maximising accessibility to opportunities in the environment" (Miller, 1999, p. 188). The subject can also be broken up into different subgroups of society to compare them, like Kwan (1999) examined differences in space-time constraints regarding the gender of the individuals. As Geurs and van Wee (2004) state, the findings of these studies can help policy makers designing transport policies in a way that the benefits reach the target group of society. This is especially important as studies have shown that some social groups suffer from transport-related social exclusion which means they are unable to participate in everyday activities because of restraints that hinder them in their transportation ability (Neutens, Schwanen & Witlox, 2011).

An interesting application is the representation of work tasks. Time paths can be recorded for workers, the main product(s) and material parts. Doing this, power relations can be revealed and the degree of repetition in the work can be determined. Furthermore, it is possible to observe the relations and possibly knowledge exchange between workers. In order to accomplish these results, a company gets broken down into work tasks. These work tasks are brought into relation with the work time of individual workers (a worker's workday consists of lined up work tasks). Depending on the study's goal, these tasks can be examined over a production process or a whole factory. Thereupon, time paths of workers and materials are constructed and put into relation with each other for further examination (Ellegård, 2018).

Another application worth mentioning takes a completely different approach. Using the time path and its constraints, Pred (1981) proposed to combine the time-geography theory with social theories. As he states, “one finds in Hägerstrand’s time-geography a highly flexible language and evolving philosophical perspective whose core concepts of path and project readily lend themselves to dialectical formulations concerning the individual and society” (Pred, 1981, p. 5). The interesting parts for social scientists are the forming of activity bundles and the spatial and temporal constraints as one can describe adjustments made to different activities depending on choices done beforehand. These changes influence not only the choice maker but also others that are somehow interconnected with choice making or the adjusted activity. Exactly these interconnections are studied by some social scientists (Pred, 1981).

Raubal, Miller and Bridwell (2004) state yet another field of application, the user-centred time-geography. In their paper, they present a framework for improving location-based services (LBS) which, today, can only handle one request at a time (e.g. public transport route from A to B, café to eat breakfast). With the combination of time-geography and the theory of affordances (see chapter 7.2), they proposed an LBS-application that takes future plans and commitments as input and calculates an optimal arrangement of these activities, including travel and different constraints. The example Raubal, Miller and Bridwell (2004) provided is about a businesswoman arriving in a city at 6 a.m. and having a meeting two hours later. In-between, she would like to have breakfast, a bagel and an espresso, read a newspaper and make a phone call. The application then provides her with the public transport routes to the office building with a stopover at a café that serves her favourite breakfast and has a variety of newspaper at the customer’s disposal. The phone call can be done in the bus to the café as the connection is stable on this route.

## 2.3 Activity-Based Modelling

The activity-based modelling is also located in the field of geography. It considers the travel demand deriving from daily activities. It is thus some kind of mixture from the two theories already covered.

### 2.3.1 The Theory

#### 2.3.1.1 Goal

The objective of this theory is to measure human travel behaviour. It is assumed that individuals mostly do not travel for the purpose of traveling but as a means to get from the previous activity to the next (Axhausen, 2000). One decides about the details of their travel based on their schedule, which means you cannot analyse one trip at a time but have to consider the agenda of the subject as a whole to fully understand their travel behaviour. The choice of activities and travel means are constrained by decision processes, behavioural rules and the individual’s environment (McNally & Rindt, 2008). The activities carried out are placed

in a broader context and analysed in terms of their larger goal (e.g. visiting lectures for the greater goal of obtaining a degree) (Axhausen, 2000).

The data to analyse is provided by time use diaries as mentioned in chapter 2.1 (Bhat & Koppelman, 1999).

#### 2.3.1.2 Concepts

The main assumptions of this theory are named by Axhausen (2000):

- Travel is a means to get from the location of one activity to another.
- Travelling as an end is an exception and counts as an activity.
- As activity count interactions with the physical environment.
- Individual activities are part of larger personal projects (e.g. shopping to redecorate), longer-term commitments (e.g. work), or satisfy physiological or emotional needs (e.g. sleep).
- Individuals are constrained by their budgets of time, resources (money, vehicles, etc.), and social capital.
- Furthermore, their planning is constrained by the need to be available to others at certain times (in person or via phone, email, etc.) and by longer-term commitments.
- Individuals coordinate their activities with other members of their household “to optimise their satisfaction balancing short- and long-term considerations” (Axhausen, 2000, pp. 2)
- While planning an activity, choices of time, duration location and access mode are taken into account.

These assumptions show that the activity-based approach differs from the other theories mainly in the research period, as activities are perceived as part of a long-time goal. With the analysis of such long timeframes and the overall complexity of endogenous variables combined with the intricate social context, the data and today’s analytical tools are not sufficient to address the research agenda in its full spectrum (Axhausen, 2000).

### 2.3.2 The Application

The main use for the activity-based approach is the analysis of travel demand. Different modelling frameworks have been developed over the years.

The beginning of such models was established by Lenntorp (1979) with his framework called PESASP (Program Evaluating the Set of Alternative Sample Paths). It was meant to generate all possible activity pattern alternatives in a constrained environment. Though, it was done under the subject of time-geography and it neglected the identification of possible choices made by the individual (Recker, McNally & Root, 1986).

CARLA (Combinatorial Algorithm for Rescheduling Lists of Activities), developed by the Oxford University Transport Studies Unit, goes one step further. As PESASP, it takes all

activities and their durations and locations as input and generates all possible activity patterns. Additionally, it takes choices into consideration and can respond to changes in the travel environment to test different scenarios (Recker, McNally & Root, 1986).

Another approach takes the scheduling model called STARCHILD (Simulation of Travel/Activity Responses to Complex Household Interactive Logistic Decisions). It calculates the utility of each possible activity pattern with the aid of the different activities' travel time, waiting time and actual participation time. As these variables change depending on the activities already done and yet to be done, each pattern gets another utility value. So, in short, this framework rates the different possible activity patterns of an individual to determine the most beneficial (Recker, McNally & Root, 1986). It is, therefore, a mixture between the activity-based theory and the time allocation theory discussed below.

The scheduling model SCHEDULER is the youngest of them and therefore the one which supports the activity-based approach the best. As input, it takes a long-term calendar with all activities and their specifications (like location, duration, etc.). Out of this data, it generates a short-term calendar with only the most urgent activities. These activities are then sorted to minimize the travel distance and thus an activity pattern is generated. It is the only framework that takes long-term planning into account (Bhat & Koppelman, 1999).

## 2.4 Time Allocation Theory

The Time Allocation Theory is the economical approach of measuring time use. Time is given a certain monetary value to make activities comparable, similar to how it is done with market goods (Becker, 1965).

### 2.4.1 The Theory

#### 2.4.1.1 Goal

In the traditional economic theory, the household maximizes its utility by using different goods that grant a benefit for the household. It selects the goods to be used under the budget constraint such that the sum of the purchased goods' prices does not exceed the maximum available budget of the household. This budget can be increased by working and consequently exchanging time for money (Chiappori & Lewbel, 2015).

The Time Allocation Theory now adds another temporal variable to the equation. Becker (1965), who firstly defined the theory, assumes that households, consuming these purchased goods and their time, produce commodities that are now added to the household's utility function instead of just the goods, as one does not benefit from a good by just owning it but by using its services. An example would be the commodity "sleeping" which needs the good "bed" and time as input. This implements a second constraint, the temporal constraint, as an individual has only so much time to spend and they must decide between working and

therefore earning more to buy more goods, or leisure to produce more commodities (Becker, 1965).

There is however a trade-off, a decision that needs to be done by an individual or household. As mentioned above, one can exchange their time for labour and therefore money to buy additional goods. Hence, an individual can decide to devote their time only to work to generate the highest possible income, or, on the contrary, use their time only for leisure. However, as one can clearly observe, both these extremes are not practicable. The solution can rather be found between these options. For an individual in poorer circumstances, it can be advantageous to keep free time to a minimum in order to ensure survival. They also need to sleep and recover, but only to a degree that maximises their income. Nonetheless, in richer countries most people are in the advantageous position of being able to sacrifice some income for additional leisure and therefore utility (Becker, 1965).

Becker's (1965) article is one of the first (after Mincer, 1962) to consider time use in the home from an economic standpoint and the first to combine consumption and leisure to one utility function, whereas before that they were handled as distinct goods providing utility separately. With these papers, Becker and Mincer created a new modelling framework, sometimes referred to as "New Home Economics", that, today, is used for virtually all household level analyses of consumption and time use (Chiappori & Lewbel, 2015).

#### 2.4.1.2 Concepts

*Opportunity cost*

To determine the ideal allocation of work and leisure time from an economic point of view, one cannot avoid the concept of opportunity cost. This cost is basically the gain one would have had if they had decided to allocate their resources differently than they did. So, to calculate the cost of a project or activity, one does not only take the material's cost needed into account but also the gain they would have earned if they had decided to engage in the next best option (Green, 1894). For example, an individual decides to work for eight hours with a salary of $ 30.- per hour (= $ 240.- per day) less the cost of transportation ($ 10.- per day) leaving them with a net revenue of $ 230.- per day. Alternatively, they could have gone on a road trip with their friends that would have costed $ 100.- but would have gotten them happiness equal to $ 350.-, therefore gaining $ 250.-. Now, if one would only look at the monetary gains and costs the case would be clear to go working as the gain greatly exceeds the cost ($ 240.- to $ 10.-), but if you take the opportunity cost of the missed road trip into account, the cost suddenly surpasses the gain and a rational individual would decide to go on the road trip.

*Importance of Forgone Earning*

There are two determinants influencing the cost of a leisure activity, the amount of time used per unit of money (direct cost) and the cost per unit of time (opportunity cost). The less the first determinant is the more the second matters (e.g. reading a book that needs a lot of time but

doesn't cost much versus eating in a restaurant that is expensive relative to the time used). Nevertheless, despite being neglected by classical economic models about opportunity costs, they vary depending on the point in time and even the commodity time is spent on. Most of the businesses are closed in the evening and at the weekends which is why the time then is "cheaper", as the alternative to work instead does not exist. Furthermore, some activities are important for recreation, like sleep or eating, which indirectly influences the productivity at work and therefore earnings, which is why the time spent for these activities costs less than other non-recreational activities (Becker, 1965).

*Households*

Not individual people but whole households are the main subject to this theory. People not only allocate their own time but also the time of their household members. They do not maximize the utility of their own time but of the time of each individual in the household (e.g. one parent stays at home to watch the kids while the other works). Time is allocated in such a way, that the member who is the most efficient at market activities uses relatively more time for working, while the other members perform more non-market-work related activities (e.g. childcare, household chores). It also means that the time allocation of each household member changes if the market efficiency of a member increases or drops (Becker, 1965).

*Income and Substitution Effect*

To understand some applications discussed below, one needs to understand the concept of the income and the substitution effect. These effects come into play when the price of a good x changes and are mostly examined in relation to a good y, whose price stays the same, that substitutes good x.

Firstly, if good x gets more expensive, people will substitute it with good y which is now, relatively looking, cheaper, the demand for good y increases, whereas the demand for x will decrease. This is the so-called substitution effect.

Usually, good x will not be fully replaceable by good y which means the available budget is affected by the increase in price of good x. This results in a decrease in demand of both good x and good y as households have now less money to spend due to the higher expenditure in good x. This is called the income effect.

As one can observe, with a rise in good x's price, the demand will decrease, but it is ad-hoc unclear if the demand of good y will in- or decrease as either one of the two effects can have a greater influence.

This can now similarly be applied to work and leisure. When wages rise, it can be handled as if the price of good x was reduced. The demand for work will be increased as it is now cheaper relatively to leisure (substitution effect). However, as people can now achieve the same wage level with less work, the demand for leisure will increase (income effect). This

means it is unclear if the demand for work will automatically increase with a pay raise (Investopedia, 2019).

*Transportation*

In this theory, the cost of travel is attributed to the activity for which the trip is undertaken. Usually, housing costs are more expensive where many jobs exist, whereas the cost of commuting increases with the distance travelled. So, as result to an increase in income, one would think that commuting higher distances gets more acceptable. However, due to higher earnings, the opportunity cost for the time used to travel increases as well, and therefore counters the other effect in a similar way as the income and substitution effect above (Becker, 1965).

*Elasticity of Substitution*

Time can be traded for a higher income, but only to a certain degree. Depending on the input that is needed to generate a commodity, the time component can be substituted more or less by monetary means (Aguiar & Hurst, 2007). Examples would be cooking where one can save time by using a microwave (which means a high elasticity) whereas there is no time saving potential in watching TV (which means a low/non-existent elasticity).

### 2.4.2 The Application

The application of this theory is rather difficult as it is hard to gather data on this level of detail. Not only are different wage levels needed depending on the time of day, week or month an activity is carried out but also produced commodities not necessarily physical goods. They can also be some kinds of immaterial goods like an educational degree, whose output is much harder to measure in monetary means (e.g. school performance, health status). Regarding the different wages over time, most of the researchers use just one wage level per person and do not bother calculating or guessing different levels depending on the point in time an activity is carried out (Chiappori & Lewbel, 2015). For the second problem, some researchers tried to evaluate the production functions of these immaterial goods, like Heckman (2013, after Chiappori & Lewbel, 2015).

In his paper, Becker (1965) mentions some possible applications in a theoretical manner.

Firstly, he mentions the income- and substitution effect if the income rises. It not only has an effect on the work-leisure-balance (see chapter *Income and Substitution Effect*) but also an effect on the adjustment of different leisure activities, as the forgone earning carries more or less weight in the activity's cost (see chapter *Importance of Forgone Earning*). This impact can be evaluated by the time allocation theory.

Another possible application could be when the productivity of consumption time increases. This could lead to a shift to more time-intensive activities as they are now comparably cheaper to other more good-intensive commodities (substitution effect). This means, the hours of work decrease as less goods and more time are needed for this balance of commodities. But there

is also an income effect which works contrary to the substitution effect. This indicates that more goods are demanded but with no increase in work productivity, it can only be paid for by increasing work hours. Again, the overall effect cannot be determined ad-hoc and needs to be empirically analysed (Becker, 1965).

He also suggests determining the cost of time via the choices of transport means. People tend to use faster travel means the longer the distance to travel is. By setting the travel distance in relation to the chosen transportation means, one can evaluate the value of time for this individual. Also, regarding transport, the question about the commuting behaviour after an income rise could be examined, as mentioned in the chapter *Transportation* (Becker, 1965).

The last application Becker (1965) discusses, is the above-mentioned influence of household members on an individual and their time allocation, respectively the influence of a change of market productivity of one family member on the others and the time allocation of the household overall.

Butz and Ward (1979) used the “New Home Economics” to analyse the changes in fertility rates, especially during the 1950’s “baby boom” and the following 1960’s “baby bust”. Both these occurrences happened during the same economic revival. To determine the reason for these opposing incidences, they examined the salary changes of both men and women and concluded that the fertility rate positively correlates with the men’s income but negatively correlates with the women’s income. This makes sense when using the time allocation theory as childcare is expensive in goods and time. When the household income increases, one can afford the commodities a child requires, but if the woman took care of the child (as it was mostly the case then) and her wage rose, the time needed for childcare got more expensive due to forgone earnings of the mother. That is why fertility rises when the wages of men increase but decline with the salary raise of women (Butz & Ward, 1979).

Another application of Kaufman, Lane & Lindquist (1991) uses the Time Allocation Theory to examine individuals’ ability to execute multiple activities simultaneously. They then analysed how this capability has an impact on these people satisfying their societal roles and if they have enough resources (especially time) to fulfil these roles or if they experience a so-called role overload. They also examined how multitasking affects consumer behaviour.

## 2.5 Time Abundance

This is an approach from the political and economic part of science. Contrary to the other theories previously described, this method focuses mainly on the qualitative aspects of time use.

## 2.5.1 The Theory

### 2.5.1.1 Goal

The main objective of this theory is to allocate the time of a human being in a way that they are happy with how they pass their time at any given moment (Rinderspacher, 2000). This means to reverse today's understanding of prosperity, away from material wealth and towards time abundance. Unlike in the past, when people had much spare time but few goods, the tides have now turned and, in the modern age, people have access to an excess of goods (Rinderspacher, 2012). Since the goods take time to be of use to an individual, the available time seems to have gotten less and less (Scherhorn & Reisch, 1999).

### 2.5.1.2 Concepts

*Time Abundance*

In earlier centuries work was done when one earned enough money to sustain oneself. There was no need to further enhance one's income and people had time for their personal needs. This practice changed during the industrialisation (Rinderspacher, 2000). As Rinderspacher (2000) puts it, in the pre-industrial eras, the amount of worked hours were dependent on the income needed to cover all expenses. During the industrialization, this dependency got reversed. Employees now work for a fixed amount of time and receive their income, that defines the living standards of a person, according to it. In the beginning, these working hours nearly filled the whole lifetime of the working populace, but bit by bit the employees got back free time in the form of standardized after-work hours, work-free Sundays, and paid holidays due to rising productivity (Rinderspacher, 2012). Rinderspacher (2012) compares this process with an agricultural area, part of which is getting renatured.

Next to this quantitative gain of free time, it is also important that the periods that have become free overlap to guarantee time together to raise the quality of this free time (Rinderspacher, 2012).

This general free time (e.g. Sunday) is, however, more and more questioned and under pressure as corporations are eager to produce around the clock to be competitive in the globalised market. This attitude comes from a paradox the higher productivity levels have created. In earlier times, when most of the populace was in the agricultural branch, or even in the early industrialisation age, the productivity was way lower than today. This means the economic loss of an interruption in production was not as grave as it is now. So, because of the increase in productivity, the time off is getting more and more expensive (see the exemplification of opportunity costs in chapter 5.1). In short, the more the productivity increases the more expensive it gets to grant the working populace time off together (Rinderspacher, 2012).

In modern times, time sovereignty gains more and more importance. It is a sign of luxury to be free to decide what to do at any given point in time (e.g. working, taking care of sick children,

studying). It is, however, important to notice that flexible working hours do not automatically translate to time sovereignty. If the flexibility is used for the employer to balance out the working hours of their employees to the times when more work is required without taking employee needs into consideration, it does not lead to time abundance. Only if the employees can choose their working hours freely and their choices are granted, even though it might contradict the economic logic of the company, one can speak of real time sovereignty and therefore time abundance (Rinderspacher, 2012).

The last part of time abundance is the decompression of time. It is of no use to decrease working hours if the workload stays the same. This would lead to time poverty (see below). This pressure leads to people needing longer recreation phases which would negate the benefits of the gained free time due to reduced working hours. It could even lead to psychological illnesses (e.g. burn-outs), that are on the rise in the last few years and are a main reason for sick leaves and invalidity pension (Rinderspacher, 2012).

In summary, time abundance is reached if people have enough free time together with other human beings, if they can mostly determine their own time allocation, and if the time at work is not too dense to not burden their psychological health (Rinderspacher, 2012).

As these demands normally result in a lower wage level, Scherhorn and Reisch (1999) asked the question if an increase in time abundance could negate a decrease in material welfare. They discussed this matter as followed. Firstly, the age of full-time jobs is over. With a general reduction of working hours, full employment could be achieved. This would be a redistribution of monetary and temporal wealth. The now unemployed could take part in the working environment and earn their own living, while now employed people would get a share of the free time unemployed have enough of. Even though, the income of the now employed people would decrease, the benefit of more time off is thought to more than compensate for the decline of material welfare. One could now think that more free time would automatically require more money, but as explained in chapter 5.1, the household itself produces goods and services. With more time at hand, individuals can produce more goods which then do not have to be bought. This reduces the burden on the available household budget. Besides, some activities that require little or no monetary input can itself satisfy a need. With more free time, these activities could finally be executed, as else they normally get delayed due to work. This would also counter our consumer society of today. This development is essential for our very own survival as it is not possible to expand our way of life to the whole world without environmental destruction and running into a shortage of resources. Summarized, it is possible to exchange material welfare with time abundance as measurement for prosperity, but there is a need for a change of thought in our society.

*Time Poverty*

Time poverty is a modern problem. Technological advancements raise the possible output per hour and worker. Additionally, through global competition, employees need to increase their performance further and further to stay competitive. This lets the material output rise. At the same time, people are feeling stressed because of the pressure to perform. They have less time to fulfil tasks compared to a few years ago. This leads to a feeling of time scarcity and ultimately time poverty, as one has not enough time for the tasks at hand. Nonetheless, as people measure success and wealth in form of material goods, there seems no end to this development. On the contrary even, as the leading figures of our society are those who own great monetary and material wealth. This lets people emulate them, they want to be able to own the same expensive goods and use the same services (like cleaners or nannies). As the number of owned goods per person increases, the usable time per good decreases and the people do not only feel stressed during their working hours but in their free time as well, as they feel like they have to make the most out of the scarce time they have at their disposal. This development was also encouraged as the increase in production got paid out in either a pay raise or lesser working time so that people had more time to buy and consume the produced goods. This "increased the desire for more and more goods" (Scherhorn & Reisch, 1999, p. 55).

### 2.5.2 The Application

This theory is thought to be an alternative for measuring the quality of life. Instead of only using the disposability of goods as indicator, the approach measures the availability of enough leisure time and the freedom to allocate it to one's liking to indicate a nation's prosperity.

Garhammer (2001) uses the time abundance theory together with the usual material indicators to measure the quality of life in different first world countries (EU14, Japan & the USA). He combined the usual social indicators for the wealth of goods and different working hours related determinants (e.g. average working hours, amount of long hours) to measure the influence of these indicators to the perceived time poverty.

A more theoretical use of time abundance is used by Zeiher (2007), who discusses the time abundance of children regarding four different criteria. Firstly, there is the balance between preparing children for the future and their time needed to be a child, that is questioned today due to the development of starting the learning process ever earlier. The future is less and less predictable, no one knows what is asked for in the economy of the future and children realise that. Also, children are perceived and targeted as consumers while not having a regular income, and thus are confronted with monetary problems and possible income sources at an ever earlier age. Furthermore, Zeiher (2007) discusses children's natural daily rhythm and getting used to the rhythm of society through school, the children's right to their own time

allocation as the stiff working day of adults gets more and more flexible, and time needed for children to establish and maintain social contacts among themselves.

## 2.6 Related Theories

There are a lot of different theories to combine with time theories and fill gaps they might not cover. Two of these theories, the Social Practice Theory and the Ecological Theory, are discussed below. Both are being used to elaborate on some studies mentioned in this paper (see Raubal, Miller & Bridwell, 2004, Røpke and Christensen, 2012, Torriti, 2017)

### 2.6.1 Social Practice Theory

This theory is less of a theory and more of a collection of different practice approaches (Stern, 2003). Renowned practice theorists are, among others, Pierre Bourdieu and Anthony Giddens. Bourdieu (1977) created the term of habitus, that is different for each individual and defines how one thinks and acts in society. Giddens (1984) said that agency, the ability to follow one's needs, and structure, that influences one's actions depending on their socialization, have both the same influence in forming people's actions and practices.

For this paper, however, the following definition is sufficient to understand, how it can be useful for the science of time use.

This approach engages in the interaction between humans and their environment. It acts on the assumption that some sets of activities are interdependent in a way that It makes sense to combine them to one unit. If such a unit is relatively enduring it is called a practice. An individual's day is full of different practices like sleep, cook, work, etc. These practices are different for every individual and as time goes by the practices may change through various external influences (Røpke and Christensen, 2012).

This theory is of interest for time scientists as it tries to measure people's habits and how they change over time. It can also be useful for determining consumption rates as most practices have a material component (Røpke and Christensen, 2012).

### 2.6.2 Ecological Psychology

Ecological Psychology is also about the people and how they interact with the environment but from the perspective of perceiving the possibilities the environment offers. It is mainly influenced by Gibson (1979) and his theory of affordance. Gibson (1979, p. 127) "mean[s] by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment." To say it in other words, affordances are possibilities of an individual to interact with their environment.

Raubal, Miller and Bridwell (2004) used this theory to picture the constraints of the time geography approach, but it can be used in any field that engages in how people perceive and interact with their environment.

# 3. Comparison

As seen above, one can measure and analyse many different cases with all these time measurement theories. In this chapter, the differences between all these approaches will be commented on and summarized with the help of the use cases presented after each theory.

First of all, these theories come from many different fields of research and are mostly used by the scientists from these fields. That does, however, not mean it can exclusively be useful to research questions related to the respective field (e.g. Pred, 1981).

The most known theory is the time use theory. As the data collected with time diaries is very extensive regarding everyday life, it can be used for many questions concerning daily activities and habits and comparing them to other states in time or different social, ethical, age or cultural groups. Thus, it can be used to analyse how different environmental changes affect certain peer groups or even the populace as a whole. It can also help to understand certain issues regarding health and other conditions that can be affected by the people's activities. Furthermore, it can be used to analyse certain consumption rates of individuals or households.

Moreover, the data generated by time diaries is very versatile and therefore used in most of the other time theories. This also leads to a common disadvantage of these theories, the data sets needed are hard to generate as the needed information has to be very extensive. Luckily, there are organisations that collect and prepare time use data for researcher to use.

Regarding people's travel behaviour, one has two fitting time theories to work with, either activity-based modelling or time-geography, depending on the research question.

If one is more interested in the reason for travelling and which activities come before and after it, respectively provoke the need to travel, their theory of choice should be the activity-based modelling. It works heavily with different scheduling frameworks and is, contrary to most other time theories, mainly used to predict rather than just analyse travel behaviour. The data to evaluate derives mainly from time diaries. It is also the only theory to really consider the big picture of an individual's life as it assumes that the activities either are to fulfil a physiological need or account to a larger goal in one's life.

Time-geography, on the other hand, maps the daily life of an individual in a space-time diagram. Although it records the activities during the day, it places its emphasis on possibilities and constraints of travelling. It tracks interactions of individuals with the environment and between each other, referring to it as "bundles". Beside usual use cases like studying the path and the interactions of an individual over a day, it made Ellegård (2018) observe individuals, machines and their interactions in factories and other workplaces. In newer adaptions of this theory time-geographers implement different alternatives to track travel in virtual space that lead to new possibilities and constraints for its users. Depending on which alternative a researcher selects, they stay closer to Hägerstrand's original theory, e.g. Adams (1995) who maps the virtual travel in the same space-time diagram, or turn away from it, e.g. Couclelis

(2009) whose approach expands the space-time diagram to a more activity-based focus to track not only the activity itself but also its purpose and it therefore becomes very similar to the activity-based approach.

Next is the Time Allocation Theory. As it measures time in monetary means, it is most commonly used to measure how people adapt their time allocations when a monetary factor in their lives changes. These changes are mostly based on substituting leisure time with work time or vice versa, but it also considers changes within the leisure time from time-intensive activities to good-intensive activities or vice versa. This means, one can connect changes of activities or of how activities are carried out with changes of the surrounding environment of an individual, e.g. the aforementioned paper about the baby boom and baby bust of Butz and Ward (1979). Furthermore, it can measure how much time is worth to an individual in monetary means. It can therefore compare different activities and their utility to a person. No other time use theory in this paper compares activities with each other. Lastly, Becker (1965) mentions the possibility to measure the influence of other household members on an individual's time allocation depending on their possibilities on the labour market.

The last time use theory introduced in this paper is the Time Abundance Theory. It is the newest of the time theories and tries to measure the people's content with their time allocation. It is the only theory presented in this paper that focuses solely on the quality of time use. It therefore is the least dependent on data about people's detailed time allocation as the happiness can be measured through one-time interviews without the need of time diaries. Garhammer (2001), however, used time diary data for more detailed insights on people's time use and their feeling of time poverty.

As this chapter shows, there are a lot of different ways of how to make use of time theories. However, due to the amount of data needed to gather and analyse, one needs to ask the question if the result is worth the cost and if it is commensurate to the research questions and goals one has in mind. For a better overview, all the time theories are summarized shortly in table 8.1.

| Time Theory | Field(s) of Research | Research Question | Applications |
|---|---|---|---|
| Time Use | Economics, Sociology | What do people do with their time | • Picturing everyday life of different individuals for the purpose of comparing between different ethical, cultural, gender, etc. groups<br>• Explaining certain conditions people are in due to their activity schedule (e.g. health)<br>• Measuring consumption of certain goods for different activities (e.g. electricity, water) |
| Activity-Based Modelling | Engineering (Transportation) | Why do people travel | • Determining the reason for people to travel (in form of activities or long-term goals)<br>• Predicting travel behaviour based on data about activity schedules |
| Time-Geography | Human Geography | How does people's travel behaviour look like over space and time | • Mapping an individual's travel behaviour over a certain period<br>• Identifying physical and temporal constraints that hinder people from travelling<br>• Examining when and where people (and objects) interact with each other (over a day, a month, working hours, etc.)<br>• Adapting these cases to virtual means |
| Time Allocation | Economics | How much value do people's time and their activities have | • Measuring the adaption of individuals' time allocation to their monetary situation or environment<br>• Picturing the utility of different activities and comparing them<br>• Determining the influence of other household members' (financial) possibilities on an individual |
| Time Abundance | Economics, Politics | How do people feel about the quality of their time | • Identifying individuals' happiness regarding their time allocation and comparing them<br>• Determining the reason for different levels of satisfaction between cultures, over time, etc. |

3.1: The different Time Theories and their Use Cases, Source: Own representation

# 4. Changes of Time Use during the Digitalisation Era

After comparing the different time theories regarding their possible use cases, this chapter talks about how these theories can be utilized to measure and analyse impacts the digitalisation has on the society.

The digitalisation era changes people's everyday lives tremendously. The influence of the industry 4.0, the internet of things (IoT), and many more applications of new digital tools turn the society as a whole upside down. Changes include home office, travel behaviour, impact of the industry 4.0 on the workplace, influence of the IoT on different aspects of everyday life (e.g. learning, sleeping, doing chores), new governmental policies, etc. There are many different methods to measure and analyse these environmental and behavioural transformations, one of which is through the above discussed different aspects of time use. This chapter examines the application of time theories on some of these changes to give you an idea on how the analysis of people's time allocation can help understand these transformations.

One big question of the digitalisation is how it influences energy consumption. Hilty (2008) and Mickoleit (2010) define three different categories of environmental impacts that the digitalisation has. *Direct impacts* occur when the physical existence of ICT devices and services affects the environment. This includes the production and operation of ICT devices through producers and consumers. The second order effect, also referred to as *enabling impact*, arises when the use of ICT products affects the environmental footprint of other goods. The third effect is called the *systemic impact* and occurs when the adaption of ICT products encourages behavioural changes. As Røpke and Christensen (2012) state, while the first order effect is always negative, the impact of the other two categories is ambiguous, although they are mostly seen as positive when considered separately (e.g. only telecommuting or e-shopping) but should not just be aggregated for an overall view as interdependences can occur (Bieser & Hilty, 2018). In their paper, Røpke and Christensen (2012) developed a framework to measure energy consumption through ICT use in everyday life with the aid of time geography and the practice theory (see chapter 7.1)0. Firstly, they propose to measure the penetration of practices with ICT to conclude on the energy consumption of these practices. As these are primarily first-order (direct) effects, they included the time geography aspect to consider temporal and spatial implications of the change ICT brings to practices. Through this perspective, second- and third-order effects are considered too. They state that ICT softens both spatial and temporal constraints, as they enable practices to be carried out at anytime and anywhere, also encouraging multitasking (for fragmentation and multitasking see below).

This allows for a more densely packed day which means it is possible to carry out more (energy consuming) activities in a day.

Another big part of individuals' energy consumption is their travel behaviour which is significantly influenced by the digitalisation and ICT devices (e.g. home office, telecommuting, e-shopping, etc.). Besides these direct impacts, there are indirect influences of the digitalisation on individuals' travel behaviour (Mokhtarian, 2002). Mokhtarian and Salomon (2002) state four different influences digitalisation can have on the travel demand in everyday life: substitution, generation, modification and neutrality, the first two of which are usually the main subject of examination. Whereas substituting effects are usually caused by direct influence of ICT (e.g. telecommunications replace face-to-face meetings) as digital means are cheaper and faster than physical travel most of the time, indirect impacts are more complex and can lead to complementarity effects (e.g. finding a childhood friend on the Internet and meeting them in person later). One of the complementarity effects observed by Røpke and Christensen (2012) was that people who telecommuted had possibilities to allocate their travel time differently so that they could travel to work outside of the rush hours which makes travelling per car more attractive to public transport. Also, as they could allocate their working hours more flexible, they could undertake private trips during the day (e.g. taking the children to school) which they would normally not have done. Another example of indirect influence of ICT on travel demand is the so-called "fragmentation" analysed by Couclelis (2000) as well as Lenz and Nobis (2007). Through digital means, individuals are no longer bound to a place to perform an activity but can do so at different times and places. This, Couclelis (2000) argues, leads to increased travel demand.

This fragmentation approach was also picked up by Schwanen, Dijst and Kwan (2008) to explain how ICT generally affects our everyday life. They combined time geography and its constraints with the affordance theory (see chapter 7.2) to show the (partial) decoupling of activities, time, and space through the use ICT. Through digitalisation, the temporal and spatial constraints are softened, e.g. one does not need to shop during opening hours if they use e-shopping. Besides the activity fragmentation, they also mention multitasking and personalised networking as results of this decoupling. Multitasking is facilitated through ICT as new digital devises allow new simultaneities (e.g. using your phone during travel), whereas personalised networking is meant in a way that one has no need to live close to someone to keep in touch or even make new acquaintances, as the Internet allows social contacts all over the world.

Another way to measure the change ICT brings to everyday life is with just comparing the time allocation in the past and now, like Vilhelmson, Elldér and Thulin (2018) did. They evaluated time use data of teenagers in 1990/1991 (start of digitalisation), 2000/2001 (home computers became common) and 2010/2011 (ICT use became common) to compare what they do during their free-time, how the availability of free-time overall changed, and how these

changes and ICT affected their activity choices. They found that, through social changes, the amount of leisure time per day has increased by half an hour while the time spent with ICT devices has grown by an hour on average, which means that half an hour of other activities has been reallocated to ICT use. Another finding they made, is that, while the time spent for offline conversations increased, the overall time used for offline activities decreased.

This leads to another issue of the digitalisation, the social isolation that, some say, happens due to extensive ICT use. Thulin and Vilhelmson (2006) used time use data from the Swedish National Communication Surveys 1997 to 2001 to measure the spread of ICT, and in-depth data gathered in 2000 and 2002 to examine the theory of social isolation. To do this, they focussed on two processes, the privatisation, with which they mean a retreat from societal activities leading to being alone and socially isolated, and the altogether displacement of activities. When examining the time use data between 1997 and 2001, they uncovered that the spread of ICT has grown rapidly, which means that individual usage differences are now more important than accessibility for understanding ICT-based activities. Their analysis of the in-depth studies showed contradictory results. Their in-depth study showed that heavy ICT users (defined as more than 45 minutes per day) spend less time socializing in and out of home and spend more time home alone and less time travelling, thus supporting the thesis of physical isolation, both socially and geographically. However, when comparing the in-depth studies of 2000 and 2002, they found that people who increased their ICT use over time did not displace out-of-home activities, but time spent on in-home activities, mainly traditional media (TV, books, etc.). It also shows that the increase (decrease) of ICT use can be led back to a general increase (decrease) of leisure time. They conclude, that the use of ICT is not primarily determined by its accessibility but by the amount of free-time available.

The opposite approach was taken by Yin, Shaw and Yu (2011) who tested how ICT (in this case phones) can enable and support face-to-face meetings. With a space-time prism, they mapped an individual A's day to identify meeting opportunities. Then, they assumed that a second person B, who would like to meet, knows the person A's daily routine but not their non-routine activities. This means, without ICT, B can only try to catch A right before or after a routine activity or during a routine activity that allows meetings (e.g. office hours) as they do not know the other's whereabouts between these activities. However, if they can arrange a full phone communication, they can arrange a meeting. A full phone communication is either a synchronous phone communication (call), an asynchronous message communication (message back and forth) or an asynchronous mixed communication (a message followed by a call). This example shows that ICT does not need to socially isolate people but, on the contrary, can enable socializing.

With all these new possibilities for people to move around, socialize, carry out activities, and so on. either virtual or physical, another challenge arises, namely the extension of the

infrastructure. Urban planners now not only need to address the needs for infrastructure for physical travel but also for virtual travel of households and companies (Drewe, 2005). To do this, Drewe (2005) proposes to determine the households' and companies' networks in this new environment because he sees "urban planning and design […] as a search for spatial concepts satisfying the needs of household and company networks" (Drewe, 2005, p. 13). He mentions that urban planning today lacks a temporal dimension and the interdependences between time and space. These points of view are important as with the digitalisation and globalization demands can change drastically over the course of a day, week, or even month. He points out six temporal developments, the society is going through: companies pressure to function around the clock, more and more individualized lifestyles lead to less synchronized daily life, synchronizing life via work hours does not hold due to the rise of flexible work hours, women's labour participation increases since the sixties, new types of multiform mobility have emerged, and ICT has spread massively. The resulting effects of these trends and challenges for urban planners are acceleration, expansion and flexibilization. To integrate the temporal point of view into urban planning, he proposes to make use of the time geography approach.

As one can see, many questions and issues that have arisen with the adoption of ICT can be measured and analysed through time theories. Through their variety, a lot of different approaches and points of view on many subjects of different fields of research can be captured.

# 5. Discussion and Conclusions

There are a lot of different possibilities to use time theories to one's advantage. Each time theory engages in different fields of studies which makes them very versatile. They can also be used for other research not related to their fields, as done by e.g. Pred (1981). Their concepts let you make detailed analyses of parts of people's everyday life and their time allocation. However, these analyses require a vast amount of data from households which is difficult to gather. Because of this, there are some organisations that raise and provide time use data for scientists to use. This is particularly handy, as most of the time theories use this time use data for their analyses.

As chapter 9 shows, these time theories are also quite useful to picture the changes digitalisation has on everyday life. It stands out that most of the questions concentrate on the transformation of mobility in itself and the shifting cause of why one chooses to travel. Du to this development, the most used time theories to picture the changing society during the digitalisation age seem to be the time use theory and the time geography. Something that also is astonishing is that there seem to be no use cases of the activity-based modelling despite its focus on mobility. A reason for this might be that this theory is usually used to predict travel demand and, as shown above, the development of travel demand through digitalisation is hard to estimate as many opposed effects have been determined and it is not yet diagnosable in which direction travel demand will develop. Time abundance is a very new and not yet established concept. This is probably why it seems to not have been picked up yet to measure the changes the digitalisation brought to people's quality of time. Nevertheless, it would certainly be worth examining it. It is, however, quite interesting that no study about time allocation and digitalisation seems to have been issued yet. There are a lot of questions about how the digitalisation and automation have an impact on future jobs and unemployment. These effects can be examined through the time allocation theory, as it discusses consequences of changes in people's financial situation. This could also be studied through a time use approach, whose data is already gathered through above-mentioned organisations.

As one can see, some analyses regarding the impact of the digitalisation on everyday time use have been done, but there is still room for further examinations as the digitalisation has a lot of different facets and is still causing changes in our everyday life.

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