Application of an integral methodological approach to measuring the dynamics of the basic digital divide

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Abstract

The paper illustrates that, when analysing the dynamics of the digital divide, the answer to the seemingly simple question 'Is the digital divide increasing, decreasing, or is it constant?' is not straightforward. An integral methodological tool that comprehensively addresses this question will be introduced. This methodological approach is based on the assumption that none of the existing statistical measures truly communicates the essence of a certain digital divide phenomenon (absolute measures, relative measures and S-time-distance are considered). In addition, even the simultaneous reporting of all three measures is insufficient. To monitor and interpret the dynamics of the digital divide it is therefore very important to explicitly take into account future scenarios of ICT diffusion among the observed subjects (e.g. population segments, countries…). We have developed these scenarios within the broad framework of the diffusion theory (Rogers, 1962, 2003), but with a distance from two of its implicit assumptions related to the deterministic conceptualisation of the diffusion process: the form of the diffusion function and the anticipated level of the final penetration rate. It is argued that the proper measure can only be provided if we anticipate and take into account the full distribution functions of the compared subjects or population segments and the location of the subject at a certain point in time.

Introduction

The term 'digital divide' is predominantly defined by differences between people who have access to digital technologies and those who do not. The digital divide concept can be encountered in various contexts and is widely discussed in scientific and research studies. Not surprisingly, these are characterised by inconsistencies in use of the concept and they lack a uniform definition. Reasons for this may also be attributed to the fact that the digital divide involves various technologies, different units of monitoring and is dealt with at various levels of development of a certain information and communication technology ('ICT'). In addition, the development of a uniform conceptual approach is hindered by the swift changes seen in the field of ICT.

For the purposes of this paper, measuring the dynamics of the digital divide is limited to cases of the basic, i.e. the first, digital divide, which is operationalised by differences between individuals in terms of the possibility of Internet access within the domestic environment. This limit is imposed for practical reasons. Likewise, the methodological framework applied is used to only study one socio-demographic factor (e.g. age). However, the proposed framework for the digital divide study also enables a potential extension to analyses of other types of the digital divide (where motivation, willingness and skills for using new ICTs are studied; for a further discussion see, e.g. Vehovar et al., 2006) and other factors, ICTs, units and levels of study.

In the last few decades, developed countries have been characterised by a big increase when it comes to adopting new ICTs. Norris (2001: 26), one of the leading researchers into the digital divide in modern societies, provides a vivid description of digital divide studies as 'blurred snapshots of a moving bullet' (due to the incessant and swift changes). Therefore, measuring the dynamics of the digital divide is one of the most important challenges of information society studies. An overarching question in this respect concerns the dynamics of the diffusion of new ICTs in the future. Some researchers (so-called 'cyber optimists') propose that the digital divide will close automatically while succumbing to public policies and the logic of the market. 'Cyber pessimists', on the other hand, caution against the stagnation and even expansion of the digital divide, and point to the existing deeply rooted patterns of social stratification and consequent reproduction and increase of social inequalities. The key question this paper deals with is measuring the dynamics of ICT adoption; measuring and interpreting the expanding or shrinking digital divide is relatively complex. The paper therefore focuses particularly on statistical-methodological aspects of the dynamics of the digital divide.

Usually, the methodological approaches to monitoring the digital divide are marginal in theoretical discussions, while empirical analyses often focus on basic comparisons based, for instance, on absolute or relative differences in percentages of Internet use. They thus offer no substantial insight into the problematics. Therefore, the main aim of the paper is to show that the study of the digital divide in a time perspective requires a broader methodological approach in order to avoid biased or even misleading results. Hence a holistic and multifaceted (not a one-dimensional) answer to the question of whether the digital divide (according to age) is increasing, decreasing or stagnating (based on secondary analysis of time series data, acquired from the Slovenian Public Opinion Survey) will be provided.

1. The research problem

The key question when measuring the dynamics of the digital divide is how to establish whether the digital divide is expanding, shrinking or stagnating. Namely, while calculating the differences between various population segments, different statistical measures can give partial (and often contradictory) views about the size of the digital divide. This often leads to a situation which only allows a partial answer to the key question.

Designing a holistic methodological framework for monitoring the digital divide in the time perspective, the paper's central premise is that *various statistical measures of the basic digital divide (absolute differences,* *relative differences and S-time-distance) may lead to qualitatively entirely adverse conclusions regarding the estimation of whether the digital divide is growing, shrinking or stagnating*. Therefore, any study of the dynamics of the digital divide based solely on statistical measures is inadequate.

The proposed solution and *main argument* of this article is that, in order to conduct integral monitoring of the dynamics of the digital divide, the following are needed:

(a) a simultaneous three-dimensional monitoring of differences with static absolute and relative differences and with dynamic S-time-distance; and

(b) an explicit consideration of scenarios when forecasting future trends of ICT penetration (e.g. the shape of the diffusion functions, the initial time delay in the early stage of ICT adoption and the final level of ICT penetration).

The proposed solution will be elaborated in the section that relates to the research approach; first, let us illustrate a simplified case which clearly demonstrates how three alternative statistical measures can lead to different conclusions about the dynamics of the digital divide. The main characteristics of the novel statistical measure called S-time-distance will also be presented.

2. Absolute differences, relative differences and S-time-distance

The dynamics of the digital divide can be monitored by conventional statistical measures (absolute and relative differences) or by a dynamic measure (S-time-distance). When comparing the adoption of ICT between two or more units (population segments, states, regions etc.) in time, two possibilities arise:

- *Variable values* can be compared, measuring the adoption of ICT at given points in time. The digital divide is thus calculated – for each measured point in time – based on the absolute or relative difference between values of the monitored variables.
- On the other hand, *points in time* can be compared at given variable values measuring the adoption of ICT. The digital divide – for every chosen value i.e. level of variable – is calculated on the basis of the difference between two temporal points. Thus, the time difference, i.e. the distance between different points in time, is measured when the compared units achieve the given level of a certain indicator.

In order to obtain a holistic insight into the dynamics of changes in the adoption of new technologies within the studied groups, first a simultaneous comparison of both of the abovementioned approaches to monitoring the difference are introduced: conventional statistical (absolute and relative) measures of the digital divide and temporal distance, i.e. S-time-distance. This will first be illustrated by using these three measures in a hypothetical case of monitoring the dynamics of change in the adoption of ICT in two groups

(A and B) in the period from 2003 to 2006 (Figure 1). Group A is characterised by an ICT increase from 10% to 20%, and group B from 5% to 15%.

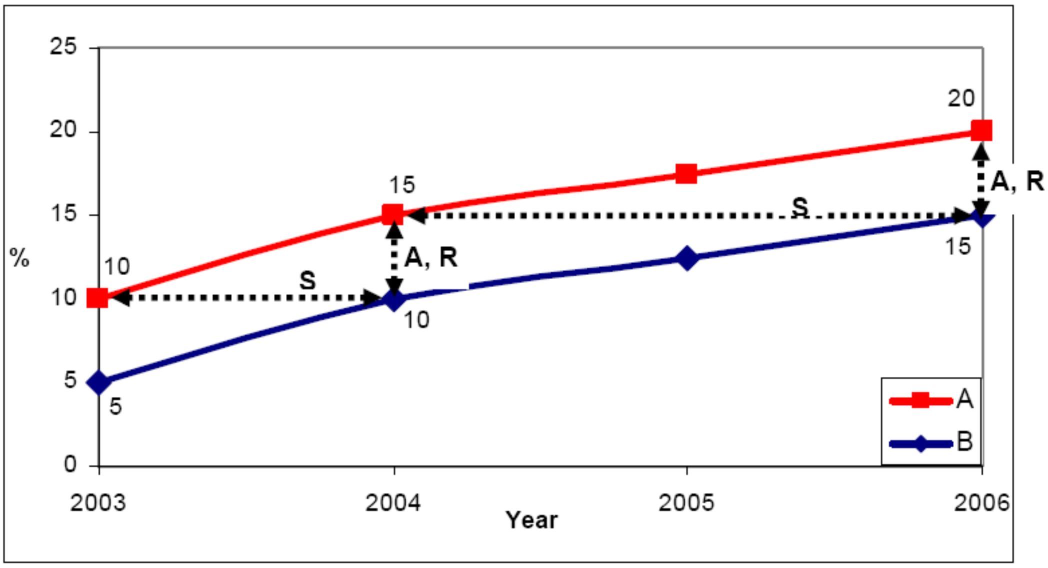

Figure 1: An example of the adoption of ICT in two compared groups (A and B) in the 2003 to 2006 period

Was the digital divide growing or shrinking in the monitored time period? The calculation of the statistical measures and corresponding interpretations are as follows:

1. **Absolute differences** are the measures most often used that, at the same time, are also the most disputable. The same absolute difference between groups A and B, with levels of 5% and 10% penetration of the Internet in 2003, is considerably more dramatic than the 10% and 15% levels in 2004, or even the 15% and 20% in 2006, despite the fact that the absolute difference – often used as the main measure of the digital divide when presented in public – is ***the same*** (5 – 10 = 10 – 15 = 15 – 20 = –5 %).
2. **Relative differences** can be calculated in many ways (this has no influence on the content aspect of the interpretation of differences); mostly, for calculating the size of the digital divide between the studied groups, the ratio and percentage difference are used. The value of the ratio between groups A and B in 2003 was 0.5 (5 /10 =0.5); in 2004 it was 0.67 (10 / 15 = 0.67); while 0.75 (15 / 20 = 0.75) in 2006. Taking these ratios into account, the digital divide is shrinking because in 2003 group B only reached 50% of Internet users as compared to group A; in 2004, group B climbed to 67% of the value of group A; and in 2005 to 75%. Percentage differences show the same figures:

- in 2003: –50% ((5 – 10) /10) × 100 = –50%;
- in 2004: –33.3% ((10 – 15) / 15) × 100 = –33.3%; and
- in 2006: –25% ((15 – 20) / 20) × 100 = –25%.

In 2003, among individuals in group B there was 50% less of those who adopted ICT; in 2004 the relative situation of group B improved by nearly 20 percentage points as group B lagged behind group A by only 33.3%. At the last temporal point in 2006 group B further improved its situation; in the adoption of ICT group B did 25% worse than group A. While in absolute terms differences between groups A and B in the two temporal points persist, relatively speaking the divide is ***shrinking***.

3. **S-time-distance**[1] expresses the time (years) within which the lagging group B will achieve the level (e.g. a certain percentage of Internet penetration) group A is at today. Thus, in 2004 the 5% (B) and 10% (A) penetration levels show that group B temporally lags behind by one year because group A reached the level of group B from 2004 (i.e. 10%) already in 2003 (see the red line, Figure 1). In 2006, the same absolute difference of 15% (B) and 20% (A) signifies two years of lagging behind because group A reached the 15% ICT penetration level already in 2004. The time delay of group B behind group A is therefore increasing; temporally, this indicates a ***growing*** divide.

The above illustration demonstrates that a simple example can yield three completely different results (even in terms of the direction of change) regarding the growth or decrease of the digital divide:

- regarding absolute differences it is stagnating;
- regarding relative differences it is shrinking; and
- regarding S-time-distance it is growing.

Due to the complex nature of the relationships between the values of absolute differences, ratios and S-time-distance, these measures are, of course, best presented synchronically, particularly if they necessitate different views on the studied problematic. In so doing, the danger of a biased estimation of differences between the studied variables can be avoided. On the other hand, this approach offers protection against potential objections claiming misleading estimates are given about the size of differences in the adoption of ICT by various groups.

Although reporting the three statistical measures is extremely informative, the question about the size of differences remains open; particularly when statistical measures show different results in the direction of change of the dynamics of the digital divide (such as the example presented above). Studying the digital

[1] In brief, time distance generally means the difference in time when two events occurred. The statistical measure S-time-distance measures the distance (proximity) in time between points in time when two series compared reach a specified level of indicator X. The observed distance in time (the number of years, quarters, months etc.) for given levels of the indicator is used as a temporal measure of disparity between the two series in the same way that the observed difference (absolute or relative) at a given point in time is used as a static measure of disparity. Thus, in addition to a static comparison, there exists in principle a theoretically equally universal measure of difference (distance) in time when a given level of the variable is attained by the two compared time series. The new view of information, using levels of the variable(s) as identifiers and time as the focus of comparison and numeraire, is intuitively understandable and can be usefully applied as an important analytical and presentation tool at various levels to a wide variety of substantive fields. For a more detailed presentation (at conceptual and applied levels) and in-depth discussion of time distance methodology (developed by Sicherl P.) consult for example Sicherl, 2003, 2004, 2005, 2007.

divide in relation to all three measures may be more informative and holistic, yet precisely because each of these measures may lead to different conclusions an almost complete relativisation of the problem may be encountered; the seemingly simple question about whether the digital divide is growing or shrinking in most cases (and in most temporal periods in the adoption of ICT) cannot be answered unequivocally. From the statistical point of view, the above example yields an entirely unclear interpretation of whether the digital divide is growing or not.

In the following sections, the values of statistical measures will be monitored in the context of the ICT adoption process where distribution functions, describing the adoption of ICT between particular groups, will be monitored simultaneously.

3. Research approach

As mentioned above, this paper aims to design a methodological framework to measure the dynamics of the basic digital divide. Here, the definition of the OECD (2001) was used, according to which the digital divide refers to 'differences between individuals, households, companies and regions related to the access and usage of ICTs.' Designing a methodological framework and understanding the diffusion and intensity of adoption of ICT, we depart from the conceptual framework of the diffusion of innovation theory. Everett Rogers, the founder of the diffusion of innovation theory (Rogers, 1962), compared diffusion to 'the process in which an innovation is communicated through certain channels over time among the members of a social system' (Rogers, 2003: 5). He defined four crucial elements of the process of diffusion of innovation – innovation, communication channel, time and social system.[2] The most relevant process for our research question is time because the study of the digital divide measures 'innovation's rate of adoption in a system, usually measured as the number of members of the system who adopt the innovation in a given time period (Rogers, 2003: 20). With this in mind, we differentiate various population segments in the system. The time element of the diffusion process allows us to classify adopter categories and to draw diffusion curves. Regarding the time needed to adopt an innovation by individuals, Rogers (2003: 410) divides the users of innovations into five categories: innovators, early adopters, early majorities, late majorities, and laggards.

The phenomenon of ICT diffusion among various subjects is, according to the diffusion of innovation theory, normally distributed. In Figure 2, adopter categories are represented by a probability density function. The adoption of innovation usually follows a normal, bell-shaped curve when plotted over time on a frequency basis. When ICTs are diffused in time, coincidental variable *t* measures the time of adoption of ICT (here,

[2] For a detailed elaboration of the basic elements of the diffusion of innovation theory, see Rogers (2003: 12-24).

time of adoption should not be conflated with calendar time) and *f(t)* stands for the probability of a random individual adopting ICT in a certain time period. If we presume that the time of adopting ICT is distributed normally with a mean time point T=2008 and standard deviation of three years, this would then mean that 68% of individuals will have adopted ICT between 2005 and 2011. On the basis of the mean value and standard deviation the probability of a randomly chosen individual will adopt ICT in a certain period can be calculated.

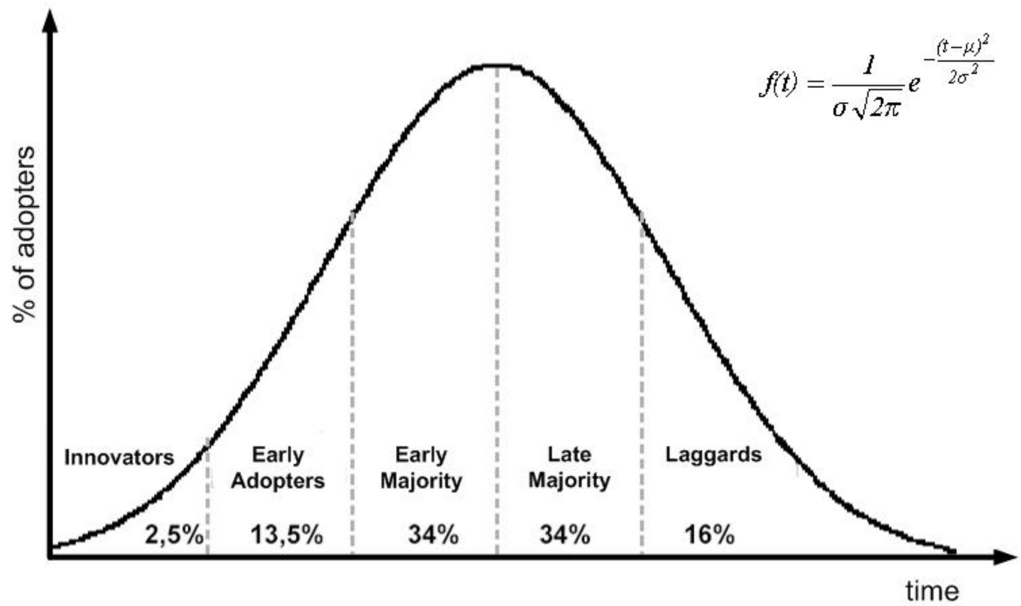

Figure 2: Adopter categories within the diffusion of innovation process (from Rogers, 2003)

A normal adopter distribution is divided into five categories by laying off standard deviations (σ) by the average time of adoption (μ). The area lying to the left of the mean time of adoption of an innovation minus two standard deviations includes the first 2.5% of individuals in a system to adopt an innovation, i.e. the innovators. The next 13.5% to adopt the new ICTs (early adopters) are included in the area between the mean minus one standard deviation and the mean minus two standard deviations. The next 34% of the adopters, called the early majority, are included in the area between the mean date of adoption and the mean minus one standard deviation. Between the mean and one standard deviation to the right of the mean are the next 34% to adopt the new idea (the late majority) and the last 16% to adopt are called laggards (Rogers, 2003).

When the number of adopters is cumulatively added and shown as dependent on time, the result is usually an S-shaped curve (Figure 3).[3] Therefore, according to Rogers's diffusion of innovation theory, the diffusion of a certain innovation (in this case ICT) is characterised by an increasing S-curve that represents a cumulative function with regard to the probability density of normal distribution as shown in Figure 2. The S-shaped adopter distribution rises slowly at first, as there are only a few adopters in each time period. The curve then rises to its maximum until half of the individuals in the system have adopted. It is then increasing at a gradually slower rate as fewer remaining individuals adopt the innovation. Hence, the S-curve can be divided into two parts, i.e. the phase of increasing growth and the phase of decreasing growth; in the initial phase, the values of the function rise faster compared to the second, gradual phase.

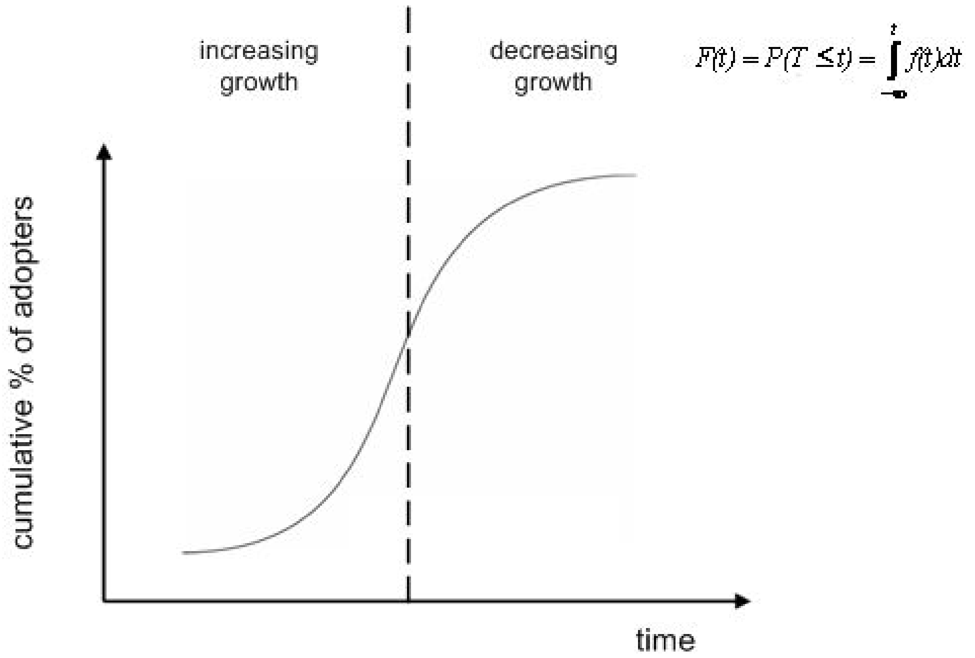

Figure 3: The cumulative S-shaped curve of adoption

The diffusion of innovation theory presupposes that between various social system members significant differences exist with regard to the time component in the adoption of innovation. In the initial phase of the diffusion process, members of a small category of innovative users (innovators) feature as actors (in

[3] F(T) is a cumulative distribution function; it designates a process of ICT adoption and is for the purposes of this paper also denominated a logistic S-curve or diffusion function because it designates the diffusion of ICT in time.

terms of the invention and adoption of an innovation) who gradually increase their influence on other individuals, i.e. the imitators. Rogers (2003) uses such social interaction between the so-called adopters-pioneers and prospective adopters to explicate the phase of rapid diffusion in the process of the diffusion of an innovation.[4]

In accordance with the diffusion of innovation theory we can assume that the divide between the observed groups is initially growing, starts to shrink when significant parts of the population reach the level of saturation and finally terminates. Roger's S-curve is widely used and has proved to be a relatively accurate description of the adoption of a new ICT, although other, slightly modified shapes of the distribution function are possible. Namely, the five categories mentioned are ideal types based on abstractions from empirical investigations; of course, exceptions to the ideal types can be found. Even when the typical S-curve diffusion models are used, the degree of saturation and pace of adoption of innovation (for instance, ICT) are not known in advance and it is almost impossible to determine them in the initial phase of adoption. In the following, the diffusion of ICT is discussed and critically elucidated from the perspective of some crucial simplifications of the diffusion of innovation theory, particularly related to the determinism of adoption growth rates and adopter categories.

3.1 Form of the diffusion function

In the eyes of policy-makers and consequently wider public opinion, the dynamics of the adoption of ICT are often designated and described by the use of a simplified and deterministic S-curve. Yet, the diffusion of innovative digital technologies, by their very nature diverse and multi-functional, is very much a complex phenomenon; its development in time cannot easily be generalised and uniformly defined by the dynamics of the increase in ICT penetration. The diffusion of innovation theory neglects the fact that this may not be the case in every instance, presuming that after the initial period of slower adoption a phase of a swifter increase in ICT penetration will occur. Norris (2001: 23-24) thus states that the diffusion of new mass media in developing countries cannot be described by a typical S-curve characterised by a typical increase in the level of growth after a certain point in time but, conversely, by slower (yet steady) growth. Unequal diffusion functions can also be observed in particular population segments within particular countries, in addition to a comparison between countries (global dynamics of the digital divide). One clear weak point of the diffusion of innovation theory – at least in terms of studying the digital divide – is the S-curve being

[4] Many researchers (mostly in marketing) have modelled the diffusion process, taking into account this characteristic of innovation behaviour, on the basis of mathematically defined equations of functions of the adoption of innovation. Three of the most often used diffusion models are the model of external influence, the model of internal influence and the model of mixed influence. However, the purpose of our study is not the study of internal or external influences on adoption of ICT. Rather, it is our aim to study the dynamics of adoption of ICT and the shape of the diffusion function *in particular population subsegments* (the presented diffusion modelling does not do this). The expected shape of the diffusion function is therefore directly based on Roger's diffusion of innovation theory, which is characterised by a normal distribution. ('Degree of innovativeness is expected to be normally distributed.' (Rogers, 2003: 272) and the corresponding distribution function is expected to be typically S-shaped; this shape of the diffusion function is close to the models of internal and mixed influence).

related to entire populations while neglecting particular population categories. According to Norris (2001), different categories are characterised by various distribution functions that comprise the S-curve typical of an entire population.[5] However, the question also arises of whether the comparison of different distribution functions will enter the so-called normalisation or stratification phase of ICT diffusion in the future; this topic is discussed in more detail below.

3.2 The normalisation and stratification model of ICT diffusion

After Pippa Norris, the author of the first influential book on the digital divide, introduced in 2001 the concept of the normalisation and stratification model of ICT diffusion, the concept soon started to be used as a critique of the diffusion of innovation theory. The normalisation and stratification model of ICT diffusion is determined by the final level of ICT penetration characteristic of the entire monitored population or particular population segments. The normalisation model can be attributed to monitored categories with a 100% (or nearly 100%) final level of ICT penetration; in categories with a lower final level of ICT penetration in at least one of the categories the situation corresponds to the stratification model.

The normalisation model (see Figure 4) presupposes that differences between groups only grow in the initial phases of adoption. The leading category (e.g. educated, younger individuals or an entire population) usually starts adopting sooner and, of course, also sooner enters the phase of swiftly increasing growth. However, in the final time period when the adoption of ICT in the leading group enters the phase of saturation, the lagging group/s reach/es higher levels of growth and the differences are eliminated.

[5] There is a chance that ICT diffusion fails to follow at least an approximation of the normal distribution (apparent in the S-shape of the diffusion function) and could be characterised by, for instance, a bimodal or even a polymodal distribution; this possibility should not be neglected. In principle, this option is allowed; later in the paper, however, we focus on kurtosis and a more or less skewed distribution.

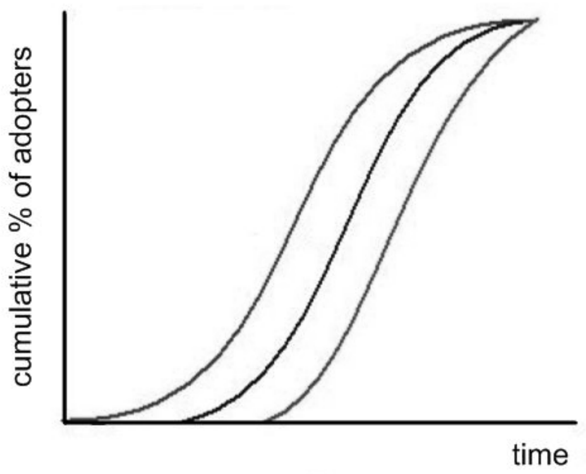

Figure 4: The normalisation model of the diffusion of innovation

The stratification model (Figure 5) presupposes that the adoption of ICT, which is characteristic of monitored categories, is described by similarly formed diffusion functions (an S-curve marked by specific levels of growth in different phases and with saturation). However, apart from the different initial point of adoption, the final point of ICT penetration differs as well. The leading category begins adoption sooner and the final level of ICT penetration is higher; in the lagging category the phase of saturation emerges at a lower level of ICT penetration.

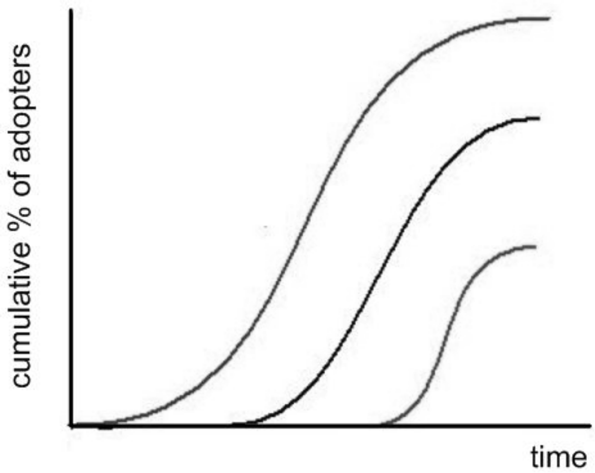

Figure 5: The stratification model of the diffusion of innovation

The diffusion of innovation theory with respect to the adoption of ICT implies that an increase in the cumulative share of adopters among particular categories in the form of the S-curve leads to an understanding of the digital divide as merely temporary differences (between these categories) that will eventually disappear. According to such ideas regarding the dynamics of the digital divide, Compaine (2001), starting from the position of the diffusion of innovation theory, maintains that it is without sense to study the digital divide as a problematic social phenomenon because the problem will be solved anyway as a consequence of market logic. Thus, Compaine ascertains that the nature of market dynamics itself will eventually lead to elimination of the digital divide – without the intervention or stimulation of policy-makers. Although the presented understanding of the dynamics of the digital divide is quite common (at least implicitly), it should be noted that the presupposition of the self-elimination of the digital divide usually includes an essential (in our opinion questionable) condition that market logic alone leads to elimination of the digital divide (supply and demand). This argument is based on the so-called 'trickle-down' principle (van Dijk, 2005), which explains the adoption of new technologies as a gradual process. This process first entangles the higher and only later on a lower social (income, employment, educational) strata (this also applies to other technological innovations). In the long run, 'the digital divide should not necessarily and self-evidently lead to toward universal social inclusion' (Hüsing and Selhofer, 2004: 23). Van Dijk (2005), Hüsing and Selhofer (2004) and Norris (2001) maintain that it is quite probable (or even more) that certain categories will never reach an equal final level of penetration of ICT compared to the level of the general population.

On the other hand, the data show that certain media (radio, TV, telephone) in developed countries have reached an (almost) total level of 100% penetration (see Schement and Scott, 2000). Huysmans and De Haan (in De Haan, 2003: 35) thus estimate – on the basis of an analogy with the penetration of telephone and TV sets – that there is a significant probability that a further diffusion of PCs and the Internet will reduce the differences between population categories; they will to a great extent eventually disappear.

Generally speaking, new media are more expensive than traditional media because they become out-dated sooner and have to be constantly up-dated with additional and supplemental hardware and software (Rogers, 2003: 13; van Dijk, 1999: 150). Moreover, it seems that lower hardware prices are compensated for by relatively expensive software and programmes. In order to use interactive audiovisual services the user has to purchase an end-user licence in addition to high-performance hardware. Besides, more and more Internet contents are payable. Therefore, the basic argument of the trickle-down principle – that computers and Internet connections are becoming cheaper by the day and eventually accessible to all – should be mitigated to a large extent.

A lower final level of ICT penetration among some population segments (or even the entire population) may be expected in technologically more advanced ICTs because computer hardware and software and network connections and services require higher input, i.e. engagement regarding both material assets, and digital skills and time. This may present (too) great an obstacle for adopting a certain technological innovation. Among important factors that influence the adoption of an innovative ICT one may, of course, also or mainly find ICT characteristics relating to hardware and software design and/or the contents offered. If individuals (regardless of their socio-demographic characteristics) fail to perceive a new ICT as useful (they do not expect it to satisfy their needs and fulfil their expectations, or they perceive the ICT as user-unfriendly or dangerous etc.), it seems very likely that individuals will not adopt the new ICT even if it were available free of charge and delivered to their home. Therefore, it is important to draw a line of distinction between individuals who cannot afford it or are insufficiently acquainted with its potential benefits and advantages, and those who reject a new ICT out of principal or for specific reasons (for them all the more valid). It is only viable to speak about the so-called late adopters or laggards when at least a potential motivation for the use of an ICT can be detected. Similarly to van Dijk, we expect that in the long run the digital divide will not be completely eliminated relative to more advanced ICTs; moreover, even the risk-free or progressive segments will most probably not reach a 100% penetration level of some (more specialised) ICTs:

> Basic computer and Internet adoption will continue to grow but advanced multimedia machines, high-speed Internet connections, and their applications probably will not reach the adoption rate of the telephone in the developed countries for the next two decades at least. We do not have to mention the developing countries – here, population wide diffusions of the old mass media are not even a realistic prospect (van Dijk, 2005: 63–64).

Of course, as happens in real life the complete, 100% adoption of an innovation is never reached. This is particularly characteristic of ICT because technological development dictates swift changes. In cases of larger technological and innovation achievements the existing technology may be completely substituted by an innovation in the process of adopting this technology.[6]

3.3 Research approach based on non-determinist definitions of the diffusion process

Now that the critical objections to the classic diffusion of innovation theory have been discussed, it is time to outline the theoretical foundations of the study of the dynamics of the digital divide.

The objects of this study are two of the key simplifications (that relate to the determinist definition of the diffusion process) of the diffusion of innovation theory: the shape of the distribution function and the final level of ICT penetration of compared segments. Alongside these two characteristics of the adoption of ICT, we also study the initial time delay among the compared segments as an equal characteristic. We thus compare (first taking theoretical values of the diffusion functions, then real empirical data) how the digital divide – in relation to the three statistical measures – changes in time if the three characteristics of ICT adoption are varied:

- Regarding the shape of the distribution function the process of ICT diffusion may be expected to be shown in various growth levels not defined by a normal distribution (typical symmetric S-curve). This is true of the entire period of adoption and particular phases of the adoption of ICT. Therefore, we can differentiate between normal distribution, leptokurtic or platykurtic distribution and a positively/negatively skewed distribution. The presumption is that the diffusion of ICT in time has to be monitored in various population segments because such disaggregated monitoring enables a deeper insight into trends of ICT adoption within the entire population. We established how the distribution functions that are valid for the entire population are differentiated in particular population segments.
- The final level of trends penetration of ICT that defines the normalisation or stratification model of ICT diffusion significantly influences the relationship between the statistical measures and the

[6] The incessant development and upgrading of ICT and new technologies as substitutes of their predecessors demands a dynamic study of ICT (van Dijk and Hacker, 2003) that acknowledges that late adopters and laggards are still in the phase of adopting the 'old' technology, while the early adopters are already in the phase of adopting a new ICT (which substitutes the old one). For instance, VCR was substituted by the DVD player already during the phase of adopting the former. Once the ICT adoption comes to a near halt (at a point, for instance, of 60%) and when such stagnation lasts for some time, we assume this point to be the point of 100% penetration. The dynamics of the digital divide are therefore only observed in the population that adopted ICT until a certain point in time (VCR); from that point onward, the adoption of DVD players is monitored.

interpretation of the dynamics of the digital divide. In the fifth chapter we will observe the increasing values of statistical measures of the digital divide (according to the diffusion of innovation theory) in the normalisation and stratification models. The two final levels of ICT penetration (50% and 70%) will be varied. Similarly, by designing scenarios we will represent cases which are expected to lead to self-elimination of the digital divide (the normalisation model) and cases where a less optimistic course of ICT diffusion will be represented (although particular distribution functions are still within the typical ICT adoption S-curve). We will also establish whether the existing data perhaps imply the normalisation or stratification model of ICT adoption in particular socio-demographic groups.

– The third monitored characteristic of ICT adoption is the initial time delay between the compared groups. Most authors who talk about the normalisation and stratification models (Hüsing and Selhofer, 2004; Norris, 2001; van Dijk, 2005) presuppose that the normalisation and stratification models are characterised by an initial time delay between the leading and lagging groups. Here, however, the initial point of ICT adoption is understood as a characteristic independent of either model of ICT adoption. In the normalisation model the studied population segments may lack the initial time delay (e.g. two groups started adoption at the same time point or period). In the stratification model only the various different-sized models have been varied, while the possibility that a delay never occurred was not anticipated. When dealing with empirical data on Internet adoption in Slovenia we determined the initial time delay at a 5% level of Internet penetration.

4. Basic elements of the methodological framework for the study of the digital divide

According to the presumption that absolute and relative differences, and time distance are a function or manifestation of the form of distribution functions, the time delay and the final level of ICT penetration, we shall examine how measures of the digital divide vary in cases of particular types. To that end, a methodological framework was designed[7].

4.1 Typology of relationships among the three statistical measures of the digital divide

In order to more accurately define the relationships between absolute differences, ratios and S-time-distance, a so-called standard typology of relationships among the statistical measures of the digital divide was introduced. As the above example demonstrates (Figure 1), each of the three studied measures may increase, decrease or remain constant. Hence, the direction of change of absolute and relative statistical

[7] Because of lack of space we do not present the methodological framework in detail; the description of the basic elements of applied methodological approach can be found within the extended version of this paper, which is available at the following URL: http://slovenia.ris.org/index.php?fl=1&nt=6&sid=120.

measures, and S-time-distance can be combined in 27 ways, which can also be equated with the potential relationships between the three measures.

The typology of potential relationships between the measures is designed in such a ways that one statistical measure corresponds to one of the three possible directions of movement (i.e. increase, decrease or constant)[8].

Figure 6 shows the case where the two compared subjects or population segments (or only a section of the time period of the compared subjects) are characterised by a distinctive combination of trends of increasing and decreasing growth (these trends could be part of a diffusion function).

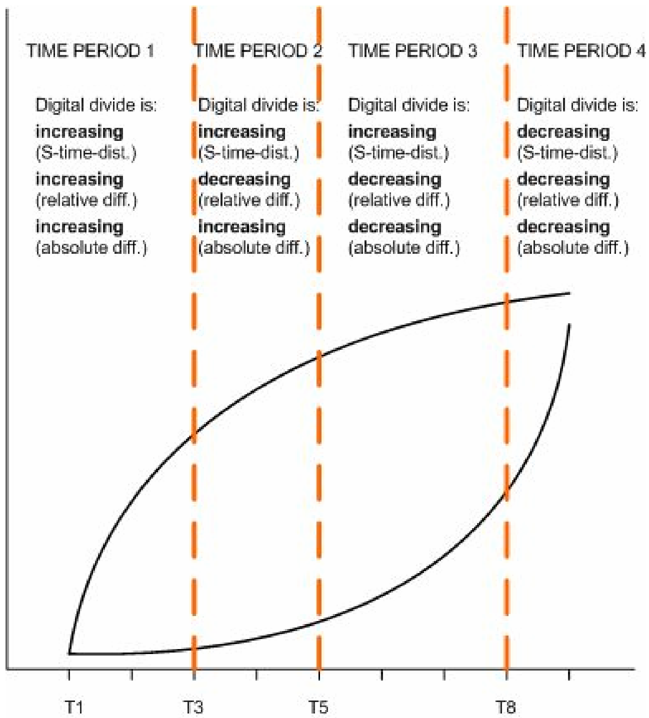

Figure 6: Comparison of two trends (increasing and decreasing growth) as part of the diffusion functions and corresponding digital divide, measured with three different statistical measures

When two subjects are characterised by different trends (as presented above) the relationship between the statistical measures changes three times, at time points T3, T5 and T8 (these changes are represented by the vertical dash line). While in the first and last time period all three statistical measures are increasing

[8] The typology of all potential relationships between statistical measures is introduced in the extended paper (see pages 11-13), which can be retrieved from http://slovenia.ris.org/index.php?fl=1&nt=6&sid=120.

(period until T3) or decreasing (period after T8), the relationships between measures of the digital divide in the middle period are more complicated. In the period between T3 and T5, the S-time-distance and absolute differences are increasing, while the differences in ratios are decreasing; in the third time period (between T5 and T8) only S-time-distance is increasing while the absolute and relative differences are decreasing.

When studying the digital divide and comparing two subjects or population segments regarding the dynamics of adoption of a certain technology, it is unfeasible to discuss one time period (as presented above) alone; several relationships emerge between two static and one dynamic measure. With the increasing number of various combinations of trends – with regard to particular diffusion functions and combinations of the two studied functions – the complexity of the relationships increases as well.

The key question of the empirical part will be the problem of identifying the type of digital divide in terms of the shape of the diffusion function, the initial time delay and the final level of ICT penetration. Thus, a change in the digital divide can accurately be interpreted and situated, and the role of the statistical measures correspondingly explained. In so doing, we can avoid incorrect interpretations of the digital divide growing or shrinking. These misinterpretations stem from monitoring only one phase in the development of the digital divide and are based on observing particular statistical measures.

4.2 Typology of combinations of two diffusion functions

In order to make the monitoring of the digital divide systematic and consistent with regard to the values of the three statistical measures, a typology of combinations of two distribution functions has been introduced, alongside the varying of three mentioned characteristics of the diffusion process (i.e. shape od the diffusion function, initial time delay and final level of ICT penetration)[9].

Here, let us briefly mention that *type* is a chosen typical case; it denotes a combination of two diffusion functions which are determined by varying the three characteristics of the diffusion process. Three types were discerned (Type A, Type B and Type C), among which the latter two are further structured as Type B1 and Type B2, and Type C1 and Type C2. In deploying key and their respective sub-types designed to designate pre-defined probability distributions the diffusion of ICT in time is described using theoretical, artificially generated values. By doing this, it was established that changing (increasing or decreasing) of statistical measures (absolute differences, ratios and time distance) is influenced not only by the shape of the probability densities and corresponding distribution functions but also by the initial time of adoption of the two compared segments and the final level of ICT penetration. In all three basic types (A, B and C),

[9] Also this typology – alongside with the key terms that facilitate an understanding of this typology and the influence of distribution functions on the relationships between statistical measures have been defined in the longer version of this paper (pg. 13-20; http://slovenia.ris.org/index.php?fl=1&nt=6&sid=120).

where appropriate, the existence and size of the time delay, and the final level of ICT penetration have been varied, in addition to various degrees of kurtosis and skewness.

We demonstrated, for example, that even in case of most rudimentary example of monitoring the delayed diffusion of innovation where both probability densities are equal and normally distributed, no one-dimensional or uniform conclusions can be drawn regarding the size of the digital divide. We demonstrated that the reason behind this is that innovation diffuses with different intensity in different periods (see e.g. Dolničar, 2007 or the already mentioned extended version of the paper).

This typology thus serves as a framework for examining how the digital divide (in terms of the three statistical measures) changes in the case of different types (of combinations of diffusion functions). It is also useful for investigating in which way the three characteristics of the diffusion process influence the relationships between the statistical measures. A Drawback of this typology is that it is limited to 14 ideal typical cases (empirical reality cannot be analysed completely). However, scenarios can be used for determining certain types (e.g. by choosing the saturation or normalisation model) and on this basis it is easier to estimate what the dynamics of the digital divide (according to an individual statistic measure) will be in the future. This enables a more informative interpretation of the relationships between the statistical measures. The next chapter demonstrates how an elaborated framework can be applied not only to theoretical simulations of diffusion functions, but also to real empirical data.

5. The digital divide in Slovenia: three scenarios for a case study on age

The in/existence of an initial time delay in the monitored groups can be monitored already in the first phase of the diffusion of ICT. Yet it is impossible to determine this for the other two characteristics of the diffusion process (shape of the diffusion function and final level of ICT penetration that is in two or more groups defined by the normalisation or stratification model). In Slovenia, the entire population reached an approximately 50% Internet penetration level in March 2005. This means that the Internet has been adopted (presupposing a normalisation model that accepts a 100% final level of penetration) by approximately one-half of all potential adopters. Thus, one of the biggest problems of studying the digital divide is insufficient information about the expected intensity of future ICT diffusion. A key question is which directions particular population segment will take in the future, i.e. what will be the shape of the diffusion function since the last measuring. A particular projection of the development of diffusion functions offers an answer to this question.

Thus, the purpose of this sub-section is to provide scenarios of Internet adoption in Slovenia; the entire population will be compared to the older age group. In the following, various scenarios will be presented;

we believe that their implementation is probable (being aware, of course, that such projections of diffusions of the Internet in the future are uncertain; thus, each scenario is open to change).

Scenarios are understood as a form of a qualitative technique of forecasting. They are narrative descriptions of possible future events and as such imply no predicting of the future (Chermack, Lynham and Ruona, 2001). Scenarios may be defined as blueprints of the future, based on schematic descriptions of some crucial presumptions. This is a probable and simplified description of the potential course of the future and is based on understandable and meaningful presumptions about crucial relationships and factors (see, Chermack, 2005; van der Heijden, 1997).

The essential characteristic of scenarios as methods that proposes multiple possible future outcomes led to adoption of this technique in anticipating probable future concepts in the field of Internet diffusion in relation to age in Slovenia. Sceptically approaching the deterministic presumptions of the diffusion of innovation theory (hence the introduction of the two key models of diffusion of innovation – alongside the normalisation model we introduce the stratification model – and the focus on various shapes of the diffusion functions), we anticipate that it makes no sense to predict only one course of events and the final outcome. On the contrary, it seems viable to outline and present several alternative possible drafts of the future. According to Bouwman and van der Duin (2003: 8), this is the first condition for using scenarios as methods of futures research.

Monitoring adoption of the Internet in households regarding age in the period between June 1996 and March 2005 [10] showed that between individuals above 60 years of age and the entire population considerable differences exist regarding all three statistical measures (Figure 7). With respect to household Internet access, the older population segment lagged behind the entire population by 33 months in October 1999; by the end of the monitoring period (March 2005) the delay had increased to 67 months. Regarding the relative differences, the digital divide between the entire population and its older segment was slightly increasing since May 2002; after that date, the elderly started to reach an ever-greater share of ICT penetration within the general population and the delay began to wane, relatively speaking. In the entire monitored period – despite the intermittent smaller decreases and increases in value ratios – the relative differences between the groups are maintained as the elderly reached 31% of the mean value of the entire population in both 1997 and 2005. Over the nine monitored years, the divide between the entire population

[10] In this paper the study of the digital divide is focused on the basic digital divide where the measure of the divide is household Internet access and the units of observation are Slovenian residents. Data are acquired from the Slovenian Public Opinion Surveys conducted by the Public Opinion and Mass Communication Research Centre at the Faculty of Social Sciences, University of Ljubljana.
Here, only one aspect of the application is discussed; in Dolničar (2007) empirical data for the diffusion of eight ICTs in Slovenia are presented: the Internet, personal computer, mobile, hi-fi, VCR, video camera, TV set and landline telephone. The diffusion of these technologies was monitored – based on available past measurements and the presence of a particular technology – in the period between 1973 and 2005. The digital divide according to Internet access was studied with respect to 13 socio-demographic variables.

and the elderly increased by 32.7% in terms of absolute differences. The digital divide between individuals above 60 years old and the overall population is constantly increasing regarding the absolute differences.

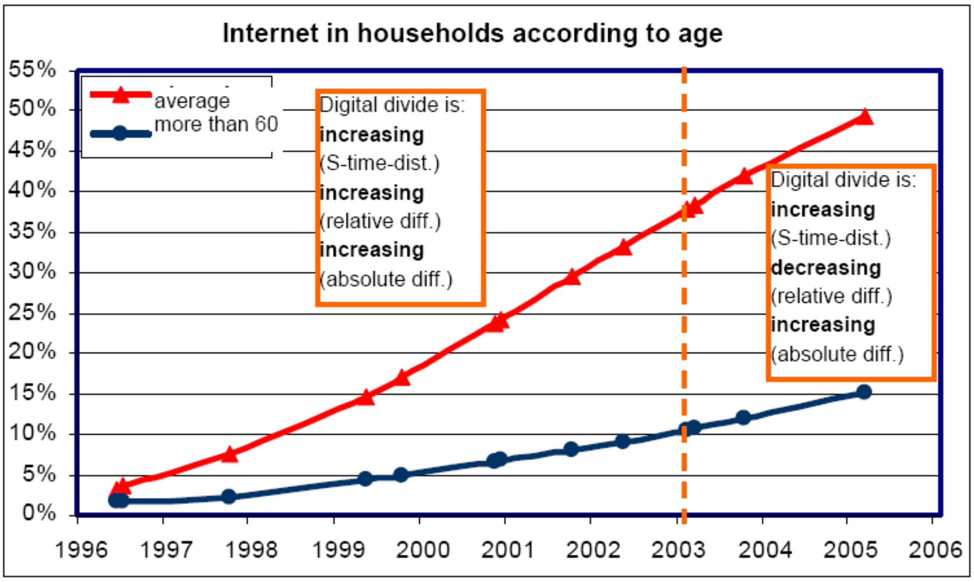

Figure 7: Diffusion of the Internet in Slovenian households among the entire population and among the older population in the 1996 to 2005 period

The values of the statistical measures and the shape of the distribution functions designate the diffusion of the Internet among the entire population and the older segment, and imply classifying this case under Type C (which denotes cases where the segment that starts ICT adoption later as the average population, is also less intensive in adoption of new technology). Thus, the older group is characterised by less intensive Internet adoption in the initial period of diffusion. In addition, there is an initial time delay between the two groups; at a 5% level of household Internet penetration the delay is nearly three years (34 months).

According to Slovenian Public Opinion Survey data, in March 2005 the Slovenian population reached a level of 49.5%[11] Internet penetration (i.e. household Internet access). Only one of the three characteristics of the diffusion process that influence the relationships between the statistical measures – the existence of an initial time delay – can be determined on the basis of empirical data at less than 50% of ICT penetration. Therefore, in the following three possible combinations of the movement of the distribution functions are presented. Based on values that determine the intensity of Internet adoption in the future, we will be able to estimate – in addition to the time delay between the observed segments – the other two characteristics:

[11] The percentage of those who have household Internet access (49.5%) is based on corrected values that result from a smoothening procedure based on trendline; the initial value was 47.8%.

the shape of the probability density function and the final level of Internet penetration. In the following, two key scenarios for Internet diffusion are presented: one with the normalisation model and the other with the stratification model (where we will consider two variations).

5.1 The normalisation model

In predicting diffusion of the Internet in the monitored groups we have been determining cumulative relative functions. Hence, the shape of the probability density was defined as a derivative of the distribution function. Prior to that, we had to estimate the values of the distribution functions (i.e. cumulative relative frequencies of diffusion of the Internet in households) that can be assigned to a sequence of uniform time periods also for the period between 1996 and 2005 because time intervals vary during the measurements of ICT penetration, varying from one month to more than a year.

Thus, Figure 8 includes cumulative relative frequencies that are valid for the diffusion of the Internet in Slovenian households among the entire population and among the older population segments in the period between 1996 and 2005. Although these values are based on real data gathered in the Slovenian Public Opinion Survey, the estimated values are presented in regular time intervals, i.e. one year. Apart from the already known empirical data, on the right side of the vertical line data are presented that show one of the possible scenarios for diffusion of the Internet in the period between 2006 and 2020.[12]

We examined how many times the relationships between the statistical measures change. Figure 8 shows the entire process of adoption of the Internet applicable to the entire population and the segment of over 60-year-olds. The bold orange vertical line at time point March 2005 differentiates real, measured data from potential anticipated values. The anticipated values present the scenario of adoption of the Internet according to the normalisation model. Each of these distribution functions is characterised by two trends. In both cases, the increasing growth is followed by decreasing growth; the decreasing growth trend is marked in lighter red and blue colours. Regarding the entire population, on one hand the increasing growth turns decreasing close to 50% Internet penetration (to be more exact, 44.8% in March 2004), in line with the theoretically defined normal distribution. On the other hand, the older population segment would, if the normalisation model were to be deployed, reach decreasing growth only towards the end of the process of adoption (as shown in Figure 8, this would occur in March 2005 at a level of 76% Internet penetration).

Let us now examine which relationships between statistical measures of the digital divide are characteristic of the household diffusion of the Internet in the entire and older population groups, respectively. Changes in relationships between the statistical measures are presented in the chart below with a dashed vertical

[12] Very different time horizons are used in forecasting, usually classified as short-term, mid-term and long-term forecasts. The 'real' time horizon varies regarding the studied research problem. The longer the time horizon, the greater is the possibility that unforeseen factors or external influences appear. This may lead to a less accurate forecast. For forecasting the diffusion of the Internet, a time frame of 14 years was taken (from 2006 to 2020). Considering other classifications of forecasts' time horizons (see, Albright, 2002; Weingand, 1995) this fits into mid-term predictions.

line – these changes occur three times. The digital divide is increasing with regard to all three monitored statistical measures in the initial monitoring period and decreasing in the final period. In the intermittent period, on the other hand, first the relative differences begin to decrease and are later followed by decreasing absolute differences. Such a sequence equals that presented in extended paper [13] when discussing the comparison between the theoretically defined diffusion functions of Type C_2 designating the comparison of the normal and the negatively skewed probability density functions.

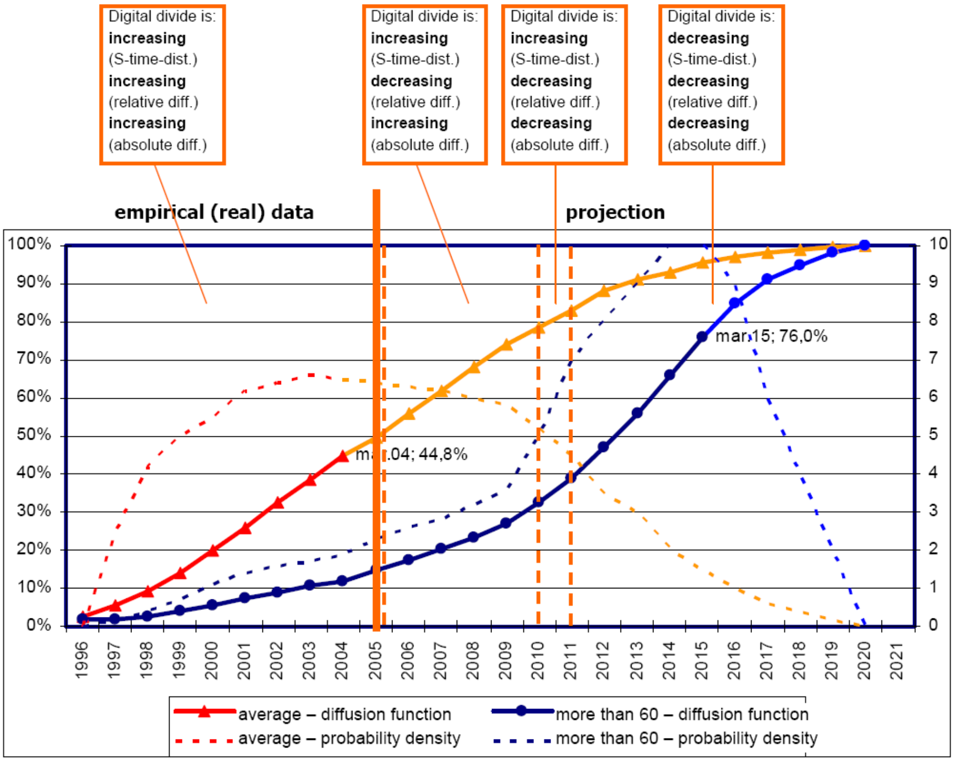

Figure 8: Projection of diffusion of the Internet in Slovenian households in the entire population and the older population for the entire period of diffusion (1996-2020); normalisation model

The following subchapter presents a projection of the diffusion of the Internet among the entire population and the older segment of the population, assuming that the diffusion corresponds to the stratification model.

[13] See http://slovenia.ris.org/uploadi/editor/1201703940Dolnicar_measuring_digital_divide_paper_jan_08.pdf, pg. 19.

5.2 The stratification model

The stratification model designates all comparisons of the two segments that describe Internet diffusion, where one segment reaches a lower level of final Internet penetration compared to the leading segment. Also in this instance, the values valid for a particular segment have been estimated for one-year time intervals (this also means the monitored period, not only the projected values).

Since the comparison entails the entire population and part of it (i.e. the older segment of the population), the leading population segment clearly cannot reach a 100% Internet penetration level (this could only be the case if the comparison were to entail the youngest and older population segments). According to data from the Statistical Office of the Republic of Slovenia, in December 2005 there were 1,671,145 Slovenian citizens older than 17 (who comprise our target population with regard to the pattern of the Slovenian Public Opinion survey). In the overall population, 413,180 (24.7%) are 60 years of age (and above); this percentage has been rounded off to 25%. Presuming that the older segment of the population will reach a 80% final level of Internet penetration, it is viable to expect that (provided all other segments will reach a 100% Internet penetration) the entire population will reach a 95% Internet penetration level.[14]

Designing the scenario of Internet diffusion up until 2020 and presuming the stratification model, we have taken into account (according to the description of characteristics of the stratification model of ICT diffusion) the S shape in both distribution functions (Figure 9). Thus, each function comprises two trends: increasing growth and decreasing growth. Here, the point of inflection, i.e. transition from one to another trend in the entire population occurs just before the second half of the process of adoption (regarding the time and level of penetration), while in the lagging group (older population) decreasing growth only occurs towards the end of Internet adoption.

[14] This percentage is arrived at by means of a simple calculation which presupposes that the older population (25% of the entire population) is reaching an 80% Internet penetration level (0.25 * 0.8 = 0.2) and the rest of the population is reaching a 100% penetration level (0.75 * 1 = 0.75); the sum of both products represents 95% Internet penetration within the entire population.

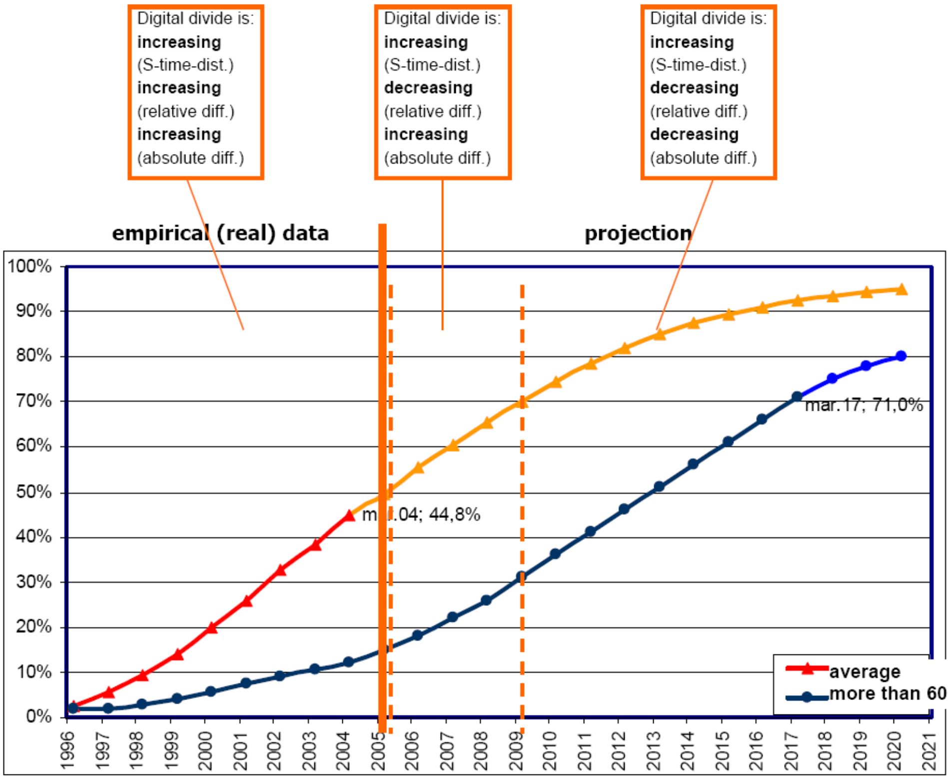

Figure 9: Projection of diffusion of the Internet in Slovenian households in the entire population and older population for the entire period of diffusion (1996-2020), stratification model (older segment reaches a level of 80% Internet penetration)

The presented compared segments again correspond with relationships among the statistical measures, also characteristic of a combination of theoretical diffusion functions in the stratification model of Type C. The above figures show that the diminishing relative differences between the two segments (starting in 2005) are a result of the trend transition from increasing to decreasing growth. Considering the anticipated scenario, absolute differences are expected to begin to decrease in 2009, with the start of a period of a swifter increase in the lagging segment compared to the entire population (the latter is, with a 70% Internet penetration level, far into the phase of decreasing growth).

To better illustrate this, let us present the third scenario of Internet penetration using the stratification model. Here, we presume that the oldest population segment will reach a mere 50% Internet penetration level by 2020.[15]

Should Internet adoption among various age groups follow this scenario (Figure 10), the differences between the entire population and individuals above 60 years of age with regard to all three statistical measures would of course be significantly greater. The presented case is particularly interesting because it illustrates constant absolute differences in the final time period. Identical absolute differences (and with them the perseverance of the digital divide) occur when both segments evolve at the same pace, but with varying levels of Internet penetration. However, this bears no significance for the S-time-distance values which are incessantly (even in the final period) increasing in both examples of the stratification model.

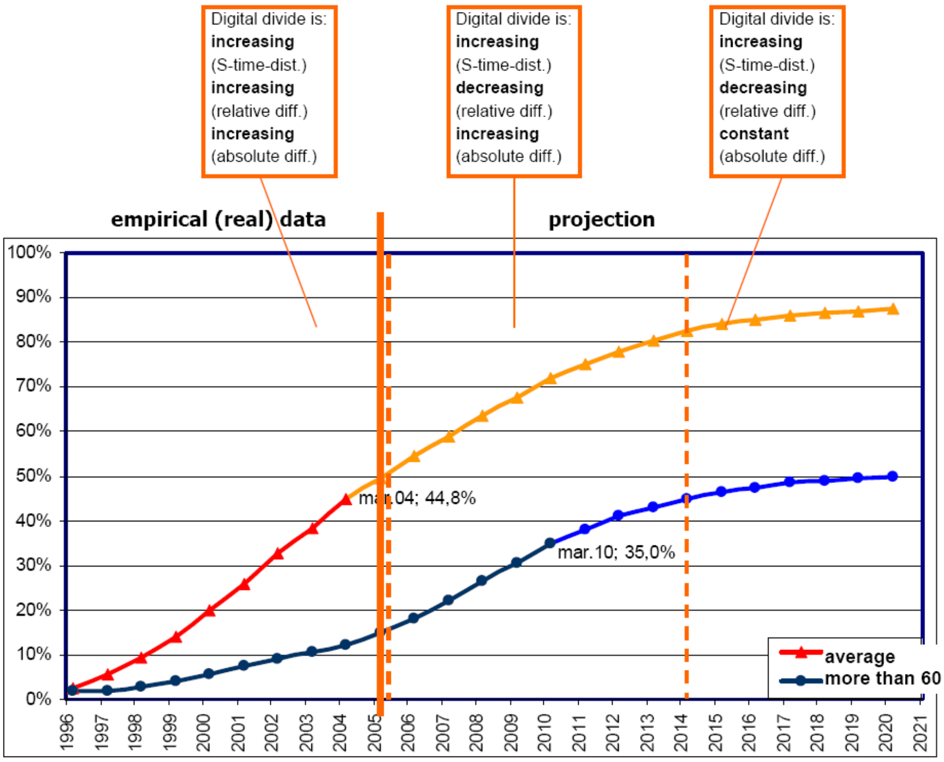

Figure 10: Projection of diffusion of the Internet in Slovenian households of the entire population and older population for the entire period of Internet diffusion (1996-2020); stratification model (older segment reaches a level of 50% Internet penetration)

[15] Presuming that the remaining part of the population reaches 100% Internet penetration, the entire population reaches an 87.5% final level of Internet penetration.

Based on the overview of the three possible scenarios of Internet diffusion regarding age, it can be maintained that monitoring the relationships between the statistical measures is only viable over the entire period of Internet adoption and not only regarding the past and present trends of the divide. Thus, for instance, the increasing digital divide between some most-at-risk groups (one of those is surely the older part of the population) and the entire population is to be expected in the initial period (this can be attributed to the initial time delay in ICT adoption). It is important, however, for us to monitor in which period the so-called inflection point will occur in the entire population (in line with the diffusion of innovation theory this can be expected at a level of about 50% Internet penetration). Decreasing differences in Type C can be expected precisely when the decreasing growth of the leading subject occurs. Of course, a shrinking divide with regard to the relative differences does not mean that the lagging subject may be expected to catch up with the entire population. This is a mere reflection of the leading subject being in the phase of decreasing growth. Explicated in the second scenario (Figure 9), even based on the decreasing absolute differences, the last, final period of ICT adoption should not be misinterpreted as the ultimate elimination of the divide. In establishing whether the diffusion of the Internet among various subjects may imply the normalisation or stratification model, the S-time-distance seems crucial. As mentioned before, it is viable to expect that the time differences between the subjects or segments in Type C will increase in the initial and intermittent period; the key question is whether the differences will start to diminish or not. If a diminishing of the S-time-distance does not occur, the stratification model may be brought into play.

Simulated and real cases were used to show that in the changing dynamics of the digital divide it makes sense to design multiple scenarios and thus provide various views on possible trends of ICT diffusion. Although the scenarios always express subjective anticipations and presuppositions, they are nevertheless valuable for establishing the future potential dynamics of the digital divide and, in addition, for monitoring the dynamics of the digital divide from the perspective of growing or shrinking differences of present and future inequalities. By designing scenarios (and with them the shapes of diffusion functions), the characteristics of growth of the digital divide – defined as crucial for explaining the notion of the dynamics of the digital divide (in addition to statistical measures) – can be clearly determined.

6. Conclusion

One characteristic of the diffusion of new ICTs in developed countries is the high degree of growth involved. Therefore, measuring the dynamics of the digital divide represents one of the greater challenges in information society research. The basic objective of the paper was to demonstrate that an investigation of the digital divide in the temporal perspective requires a wider and more holistic approach; if this requirement is not met, the results could prove to be biased and misleading. The key concern here is to establish whether the digital divide is expanding, shrinking or stagnating.

To that end, a methodological framework was designed to be used in the study of the dynamics of the digital divide. We departed from the conceptual framework of the diffusion of innovation theory, emphasising and analysing two (according to our findings) crucial elements of the theory. Yet, they are also problematic for monitoring the dynamics of the digital divide due to their determinist-normative nature. These elements (perhaps inadequately thematised by the diffusion of innovation theory) refer to the shape of distribution functions, which designate the diffusion of ICT and the final level of ICT penetration in compared groups. Regarding the shape of the distribution function it was expected that the diffusion of ICT may unravel over various growth phases not necessarily congruent with a normal distribution (in the cumulative shape this means the S-curve symmetric diffusion function). Accordingly, we differentiated between the normal distribution, kurtic distribution and skewed distribution. Thus, we departed from the presumption (unlike classical studies of the diffusion of innovation theory) that ICT diffusion in time has to be monitored in various population segments; such disaggregated monitoring enables a profound insight into ICT adoption trends among the entire population. Another critically evaluated key element taken from the diffusion of innovation theory that was also included in the design of our methodological framework can be noted in implicit theoretical presumption that the digital divide will diminish by itself; the entire population (with all its segments) is supposed to reach a 100% level of ICT penetration. To the contrary, this study of the digital divide considered more potential final levels of ICT penetration; therefore, alongside the usual normalisation model a stratification diffusion model was introduced.

Considering the abovementioned characteristics of the diffusion process we acquire a more holistic insight into the dynamics of changes in ICT adoption in studied segments, particularly where the three statistical measures (absolute differences, relative differences and S-time-distance) display different possibilities regarding the direction of change of the digital divide. Namely, reporting of results based on all three measures yields a more informative and holistic insight into the studied dynamics – however, the question about the size of the differences may remain unanswered. This can lead to a methodological quandary, an utterly blurred field that leaves no uniform answer to the question about the growing or shrinking digital divide (moreover, three contradictory answers are possible). Because of the complex relationships between the statistical measures it is thus recommended: (a) to present all of them (thus we can avoid potentially one-sided, partial estimations of the disparities); and (b) to interpret the extent of the digital divide according to the presumption that statistical measures are a function, i.e. manifestation, of the shape of distribution functions, time delay and final level of ICT penetration.

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