

Determinants affecting the set-up of dental practices in Germany

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Abstract

Regarding a peril to full-coverage dental care, it is reasonable to find a method to identify the crucial determinants affecting dentists' decision to set-up a practice (office).

METHODS: A systematic literature review was conducted for the years 2010-2020 using the databases Elsevier-Scopus, Springer-SpringerLink and MedLine-PubMed. The factors found in the literature were compared in a pairwise comparison within the framework of a pilot study and could be weighted using the Analytical Hierarchy Process (AHP) and verified for their consistency.

RESULTS: Nine factors could be identified. They got weighted: quality of life in private environment (24.12%), environment for the family (20.26%), infrastructure (14.80%), location of the practice (9.72%), real income (7.51%), support programs (6.86%), professional cooperation's (6.39%), dentist density (5.51%), funding conditions (4.82%). The consistency check resulted in CR=0.06 and is considered consistent.

CONCLUSION: The AHP method is a way to analyse relevant factors for the setting-up of dental practices. The AHP can be used as an approximation method for further analysis of business types and socio-demographic differences within the dental profession.

Keywords: dental care, analytical hierarchy process, multicriteria decision-making

JEL codes: A100, A110

1. Introduction

There are many personal aspects that influence a decision. A dentist's decision about setting up his own practice has also social implications. The global pandemic reminds about the relevance of an adequate, full-coverage healthcare.

Consequently, there is a need to prevent potential shortages in the health care system. This is the context of this paper.

1.1 Self-employment in dentistry in transition?

The set-up of new dental practices in Germany has been fallen since 1999, as the following table shows.

Table 1: New dental offices in Germany

Year	New dental offices in Germany	Source
1993	Ca. 4.000	Kaufhold, 2000
1999	Ca. 2.500	Kaufhold, 2000
2012	1.195	Klingenberger, 2018
2018	1.214	Bundeszahnärztekammer, 2019

The forecast of the care atlas for the federal state of Rhineland-Palatinate shows a total of 1,524 dentists in need of replacement by 2023, which corresponds to more than half the dentists currently working in Rhineland-Palatinate (Kassenärztliche Vereinigung Rheinland-Pfalz, 2019).

Dental care will be a problem in certain regions, especially rural regions. More than 4,500 inhabitants must be covered by a single dentist (Kassenärztliche Vereinigung Rheinland-Pfalz, 2019), while the national average were 1,147 inhabitants per dentist (dentist density) in Germany at the end of 2020 (Kassenzahnärztliche Bundesvereinigung, 2021).

Forecasts predict no general change in this ratio (Brecht, Meyer und Micheelis, 2009). This distribution appears to be unfavourable and self-employment to be declining.

While the population per dentist remains nearly constant, the ratio of self-employed dentists to employed dentists is visibly changing in favour of employment. In 2011, 82.5% are self-employed and in 2020 it is down to 65.8%.

Table 2: Development of dentist density in Germany (Kassenzahnärztliche Bundesvereinigung, 2021)

Year	Population	Dentists (total)	Dentists (self-employed)	Dentists (providing treatment)	Inhabitants per practising dentist
2011	80.328.000	87.539	54.286	68.502	1.173
2012	80.524.000	88.882	53.767	69.236	1.163
2013	80.767.000	90.147	53.497	70.074	1.153
2014	81.198.000	91.610	53.238	70.962	1.144
2015	82.176.000	92.966	52.772	71.629	1.147
2016	82.522.000	94.312	51.971	71.886	1.148
2017	82.792.000	95.670	51.014	72.124	1.148
2018	83.019.000	97.028	50.033	72.601	1.143
2019	83.167.000	98.313	48.878	72.575	1.146
2020	83.155.000	99.569	47.697	72.468	1.147

The reasons for the decrease of dental establishments must be researched.

Looking at the average age of dentists starting a business, it rose from 1994, when they were under 34 years old, to 36.9 years in 2014 (Klingenger and Köhler, 2019).

In general, the trend towards a "feminization" of the dental profession can be assumed (Brecht, Meyer und Micheelis, 2009). The number of women in dentistry increased. In 2018, for the first time, as many female dentists (607 of 1,214) as male dentists were established (Klingenger and Köhler, 2019). In a representative survey, students of dentistry were asked what their ideal profession would be. In the survey, 71.4% of men chose self-employment, while 56.7% of women chose self-employment (Klingenger, 2018).

Female dentists tend to start a practice to a lesser extent than their male counterparts (Bundeszahnärztekammer, 2019). Gender differences in terms of financing volume remained in 2018. Men invested an average of EUR 711,000 in the start-up of a single dental practice, 39% more than women, who invested an average of EUR 513,000. When taking over a single practice, the financing volumes of female dentists, at EUR 356,000, were about 18% lower than the investments of their male colleagues, who invested EUR 434,000 (Klingenger and Köhler, 2019).

In this regard rising investment costs for a dental practice must be considered. In 2018, the average financing volume for founding a practice was 598,000 euros (Klingenger and Köhler, 2019). In 2014, an average start-up investment of 422,000 euros was necessary. This means that the investment volume has increased by 42% in only four years.

Since 2007 (Vertragsarztrechtsänderungsgesetz, 2007), dentists can be permanently employed. While in 2006 there was an average of 0.12 employed dentists per practice, in 2016 there were already 0.32 employed dentists (Kassenzahnärztliche Bundesvereinigung, 2018). In 2007 (Gesetz zur Stärkung des Wettbewerbs in der gesetzlichen Krankenversicherung, 2007) the previously existing barriers to establishment were lifted for dentists; unlike physicians, there is freedom of establishment. In 2000 89% of all dentists providing dental services were self-employed. Today proportion of self-employed dentists in dental offices is only 66% (Bundeszahnärztekammer, 2019).

The complexity of this situation leads to the question: What factors influence the decision of dentists to set up an office? What influence have local environmental factors on founder's decision on the business type of practice?

1.2 State of research and gaps

Several aspects of decision-making regarding setting up a practice have already been analysed. Many studies can be found in the field of general practice.

Some studies have examined financial aspects. In this context, correlations between real income and the motivation to start-up have been discovered (Günther, 2010; Steinhäuser, 2011; Steinhäuser, 2013; Voltmer, 2017; Deutsch, 2020).

On the political side, relations to financial incentives, support programmes, were also evaluated (Kittel, 2016; Vogt, 2016).

In addition to these economical aspects, private factors are of significance. Subjective reasons for motivation have been verified in several studies in this context (Roick, 2012; Stengler, 2012; Steinhäuser, 2013; Voltmer, 2017; Küpper, 2018).

Other influencing factors are the quality of life in private environment (Kiolbassa, 2011; Scholz, 2015; Schmidt, 2017) and a family-friendly environment (Stengler, 2012; Steinhäuser, 2013; Scholz, 2015; Kasch, 2016; Barth, 2017).

The relevance of professional networks has been widely confirmed in research as well (Günther, 2010; Steinhäuser, 2011; Scholz, 2015; Kittel, 2016; Schmidt, 2017; Küpper, 2018).

Structural elements are considered to influence the decision as well. It is evidently relevant where a dental practice is founded. Besides the location, the region of the practice (Deutsch, 2014; van den Bussche 2016; Vogt, 2016; Mays, 2019; Kettler, 2019; Klingenger und Köhler, 2019) and the infrastructure are decision factors too (Kiolbassa, 2011; Steinhäuser, 2013, Scholz, 2015).

The contribution of competition has also been studied (Jäger, 2016; Vogt, 2016; Voltmer, 2017; Kettler, 2019; Klingenger und Köhler, 2019). This can be measured with the so-called dentist density coefficient (inhabitants per dentist).

The impact of the above-mentioned determining factors is mainly related to general practitioners in the conducted research.

However, research that has been conducted covers these factors only selectively and mostly focuses on general practitioners, students and political actors, and to a lesser extent on dentists.

In a Germany-wide cross-sectional study with 480 dentists, the assessment of the general situation on basic motives and future visions of dentists was questioned to investigate the choice of business types for dental practice (Matusiewicz, 2016).

A study from the University of Minnesota School of Dentistry in the United States of America examined 106 out of 369 dental students in their final year of study from 2016 to 2018. A 10-item questionnaire before and after a four-week university programme (rotation) in rural areas was used to evaluate the relationship between the size of their hometown and their intended practice location. The second objective was the assessment of the influence of university programmes for rotations in rural areas (Mays, 2019).

A longitudinal study by Nele Kettler was conducted with a broad data base (Kettler, 2019). In the first survey in 2015, 1.367 participants participated (Kettler, 2017). In the second survey, 599 respondents (dentists in training) from the group of participants in the first survey took part. The question about the future distribution of dental practices was evaluated with a 31-item questionnaire. As a result, small and less populated areas were considered a region of interest by less than 10% of respondents. The majority (48.4%) of the participants wants to work in larger medium-sized cities (<100,000 inhabitants) and (48.3%) in smaller large cities (<500,000 inhabitants). Only 20.4% can imagine working in rural communities (<5.000 inhabitants). Half of the respondents would like to settle in the current region of activity. When changing location, mainly neighbouring regions were considered.

All the determinants mentioned appear to influence dentists' motivation in terms of their decision to set up a dental office. Since health care providers have comparable policies, it can be assumed that all the factors described are of same relevance for dentists.

In identifying why dentists choose to be self-employed in a particular business type of practice or to be employed, it seems appropriate to consider all factors investigated as relevant.

The intended methodological approach of this publication is to establish a framework for the evaluation of the factors relevant to the business set-up by the agents themselves, thus making it possible to answer the research questions that arise in the follow-up.

In the spirit of recruitment, this work should be able to answer the questions in terms of supporting and guiding new dental offices.

1.3 Multicriteria decision problem

Descriptive decision theory aims to describe how decisions are made in reality, and to explain why they are made in one way and not another.

Its goal is to find empirically valid hypotheses about the behaviour of individuals and groups in the decision-making process, with the help of which decisions can be predicted or controlled given knowledge of the respective concrete decision-making situation (Laux, 2018).

Many approaches to descriptive decision theory have developed. In all descriptive decision theories, decisions can be empirically examined (Tsoukiàs, 2008).

A method of Multi-Criteria Decision-Making (MCDM) can solve the emerging issues for this case, because it copes with the central problem how to evaluate a set of alternatives in terms of a number of criteria. One method is the Analytic Hierarchy Process (AHP), pioneered by Thomas L. Saaty. There are several other methods such as weighted sum model (WSM), weighted product model (WPM) and TOPSIS (for the Technique for Order Preference by Similarity to Ideal Solution). Triantaphyllou gives an overview about more of these methods (Triantaphyllou, 2000).

Looking at the actors in the case of dentists', their values of criteria are not exactly quantifiable and cannot be accurately estimated. Their decision relates to financial, political and social aspects. Therefore, a common type of utility analysis seems unsuitable for answering the questions addressed in this paper.

The Analytic Hierarchy Process (AHP) offers the advantage that complex decision-making processes can be decomposed into small units (pairwise comparisons), structured and formally solved. It is analytical, as the decision support is mathematical and by means of logical reasoning. It is hierarchical because the decision problem is broken down into a hierarchy of criteria and alternatives. Moreover, it is defined as a process because of the procedural nature of making decisions.

Both subjective factors, such as social or political aspects, and objective ones, such as legal or economic aspects, can be included in the analysis.

Through the AHP, the importance of the factors can be assessed in relation to each other, and the available information can be used to take a decision. Thus, the most significant difference to the classical scoring model is that the evaluation does not only distinguish which factor or which result is better or more important, but also how much better or worse the respective variable is.

Looking at the framework of Davood Sabaei et. al. (Fig. 1) it becomes clearer that AHP is the needed tool to evaluate the questions arising (Sabaei, 2015).

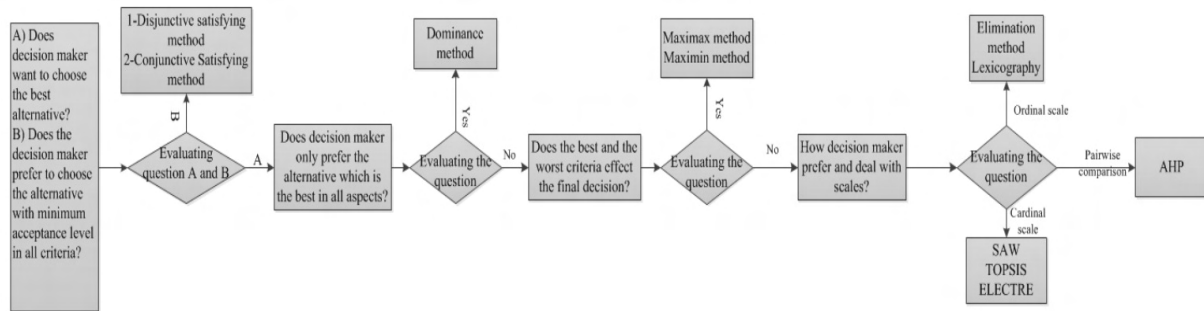


Figure 1: Process of selecting MCDM method based on decision maker (Sabaei, 2015)

2. Methodology and data

The identification of the relevance of the factors for the decision on the dentist practice type was based on a systematic literature review in the first phase.

Analytic Hierarchy Process with the synthesized factors was designed in the second phase.

An online survey in the third phase enabled dentists to make pairwise comparisons of factors and provide data input for their analysis according to T. Saaty's approximation method.

2.1 Systematic literature review

To identify relevant studies, the three largest electronic databases for medicine-associated journals (Elsevier-Scopus, Springer-SpringerLink, MedLine-PubMed) from 2010 to August 2020 were searched. The search was conducted with specified keywords from May 2020 to August 2020.

A systematic literature search was conducted according to this methodological approach, which was described by Cooper in 1998.

For this purpose, the preparation of a coding sheet to collect primary research reports was carried out according to Cooper's criteria (Cooper, 1998):

First, background information was retrieved to identify the particular report. These were the following characteristics: The authors of the report, the source of the report, when the report was published, and which information channel led to the discovery of the report.

It was possible to include 33 relevant studies in the systematic literature search.

The studies included can be divided into five different focus groups (financial, geographical, personal, regulatory, educational).

The criterion called "setting of the study" by Cooper is in this case the information that covers one of the five aspects mentioned.

Eligibility Criteria

Inclusion criteria: publishing year between 2010-2020, studies with focus A: financial aspects, focus B: geographical aspects, focus C: personal aspects, focus D: regulatory aspects

Exclusion criteria: not published in English or German, not peer-reviewed, no quantitative analysis, literature reviews and meta studies

Information Sources

PubMed (MEDLINE), SpringerLink (SPRINGER) and Elsevier (SCOPUS)

Study Selection

The study selection was conducted sequentially as follows:

1. Search literature using 54 keywords in combination “or”/”and” in the databases PubMed (MEDLINE), SpringerLink (SPRINGER) and Elsevier (SCOPUS)
2. Screening of title, abstract, and keywords were conducted based on eligibility criteria
3. Eliminating articles not meeting the eligibility criteria
4. Scanning the references of the articles to find related Studies

Qualitative and quantitative as well as national and international studies in German and English were accepted, which dealt with characteristics of doctors and dentists relevant to the setting up of a practice or work, which assessed characteristics relevant to the setting up of a practice from a dental, medical or administrative point of view.

Publications that only contained background information on the topic under investigation, as well as individual opinions, and field reports were excluded.

2.2 The Principles of the Analytical Hierarchy Process

The principles of the AHP are based on four axioms established by Thomas Saaty (Saaty, 1987).

2.2.1 Saaty's Axioms

Axiom 1

Reciprocal: Given two alternatives (or criteria) i and j from the finite set A of all alternatives. The decision-maker is then able to specify a value a_{ij} for the comparison of these two alternatives with regard to a criterion c from the set C of all criteria on a ratio scale, so that applies:

$$a_{ij} = 1/a_{ji} \text{ for all } i, j \in A$$

Axiom 2

Homogeneity: If the decision maker compares any two alternatives $i, j \in A$ with respect to a criterion c from the set C , one alternative is never infinitely better than the other alternative, it holds:

$$a_{ij} \neq \infty \text{ for all } i, j \in A$$

Axiom 3

Hierarchy: It is possible to represent the decision problem as a hierarchy. Each level only influences a higher level and is itself only influenced by the level below. The elements of a level must not influence each other.

Axiom 4

Expectations: All criteria and alternatives that have an influence on the decision problem are included in the hierarchy.

2.2.2 Elaborate Design

T. Saaty also developed an **AHP elaborate design** (Saaty, 1990):

1. Identify the overall objective
2. Identify sub-objectives of the overall objective
3. Identify criteria that need to be met to fulfil the sub-objectives of the overall objective.
4. Identify sub-criteria under each criterion
5. Identify the actors involved
6. Identify goals of the actors
7. Identify the policies of the actors
8. Identify options for action or outcomes

„It is designed to cope with both the rational and the intuitive to select the best from a number of alternatives evaluated with respect to several criteria.” (Saaty, 2012)

The decisions of dentists according to the analysis of several studies (e.g. Barth, 2015; Günther, 2010; Kasch, 2016; Kettler, 2017; Kettler 2021; Steinhäuser, 2011), depend on rational as well as intuitive decisions and are always subjective in particular instances. Therefore, the model of the Analytic Hierarchy Process is a suitable tool for analysing complex multi-criteria decisions of the group under investigation.

2.2.3 AHP Modell (T. Saaty, 1990)**Step1**

Hierarchy: In the first step, the decision problem must be structured in a hierarchy. As sketched in the Figure 1, the decision problem or goal (level 1) is broken down top-down into criteria (level 2). At the lowest level, the alternatives (level 3) are listed.

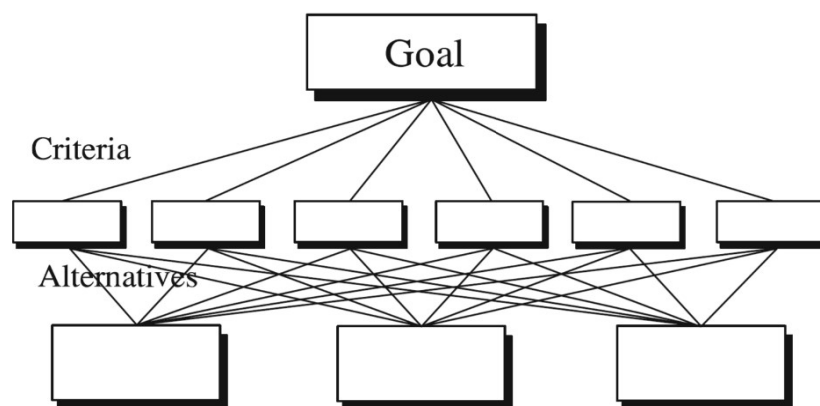


Figure 2: Hierarchy of AHP (Saaty, 1990)

Step 2

Pairwise comparison: In the second step, the weighting of all elements of a hierarchy level must be determined regarding each element of the next higher level to which it is related.

The amount of pairwise comparisons of the criteria results from the following equation:

$$\text{Number of pairwise comparison} = \frac{1}{2}n \times (n - 1)$$

The AHP assumes that the persons involved in the decision-making process are overburdened with the task of directly assigning weights to hierarchical elements. Therefore, the determination of importance is based on a scale developed by T. Saaty (Saaty 1980).

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity <i>i</i> has one of the above nonzero numbers assigned to it when compared with activity <i>j</i> , then <i>j</i> has the reciprocal value when compared with <i>i</i>	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining <i>n</i> numerical values to span the matrix

Figure 3: Fundamental scale legend (Saaty, 2012)

Based on the evidence of the psychologist George A. Miller, T. Saaty designed his scale (Saaty, 1987). Miller proved in 1956 that short-term memory can only remember 7 ± 2 "pieces of information" (Miller, 1956).

Different standards to linear scales (Saaty, 1977) for comparing two alternatives are described. They are known as scale of Power (Harker & Vargas, 1987), Geometric (Boender, 1989), Logarithmic (Ishizaka, Balkenborg, & Kaplan, 2010), Root square (Harker & Vargas, 1987), Asymptotical (Dodd & Donegan, 1995), Inverse linear (Ma & Zheng, 1991), and Balanced (Salo & Hamalainen, 1997).

For a detailed discussion of the merits of the scale, see (Saaty, 1980).

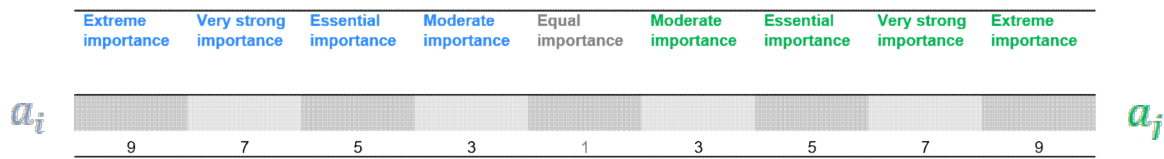


Figure 4: Fundamental scale example

The variable a_{ij} stands for a comparison pair from the set of comparison pairs a_{nn} .

The decision maker can thus evaluate between two elements i and j from the finite element set A with respect to a criterion from a set of elements.

$$A = (a_{ij})$$

This is done by means of a pairwise comparison a_{ij} based on a metric scale. The scale is reciprocal, so that applies:

$$a_{ij} = 1/a_{ji} \text{ or } a_{ij}a_{ji} = 1 \quad (a_{ij} > 0; i, j = 1, \dots, n; i, j \in A)$$

The results of the pairwise comparisons can be represented in matrix form.

Based on the theorem of Perron-Frobenius (Perron, 1907), which states, in the case of the existence of a positive eigenvector, to a positive eigenvalue of non-negative matrices with the largest amount:

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{pmatrix} > 0 \Leftrightarrow a_{ij} > 0; i, j = 1, \dots, n$$

Step 3

Priority vector or Eigenvector: In the third step, the weighting vectors are determined based on the matrices with the results of the pair comparisons. On the one hand, this can be done by an approximation method. On the other hand, an exact calculation is possible within the framework of an iterative process.

The exact calculation can be regarded as the theoretical foundation of the AHP. In the literature it is called the eigenvector method (Saaty 2012).

According to this, the calculation of the weights at Level 2 follows:

$$A_w = \begin{matrix} & A_1 & \dots & A_n \\ \begin{matrix} A_1 \\ \vdots \\ A_n \end{matrix} & \begin{bmatrix} \frac{w_1}{w_1} & \dots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \dots & \frac{w_n}{w_n} \end{bmatrix} \end{matrix} \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = nw$$

The column sums of A are formed to calculate the normalised pair comparison matrix ($A' = a'_{ij}$) (Ishizaka and Labib, 2011).

For the exact calculation, computer-based programs like superdecisions or Expert Choice are available (Ishizaka and Labib, 2009). An approximation is made according to T. Saaty by forming normalised columns. An approximation for an eigenvector is the average of the column vectors (Saaty, 2012):

(1) Sum the elements of each column j :

$$\sum_{i=1}^n a_{ij} \quad (\forall) i, j = 1, \dots, n$$

(2) Divide each value by its column sum:

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}$$

(3) Mean of row i :

$$p_i = \frac{\sum_{j=1}^n a'_{ij}}{n}$$

Step 4

Consistency: If a_{ij} represents the importance of alternative i over alternative j and a_{jk} represents the importance of alternative j over alternative k and a_{ik} , the importance of alternative i over alternative k , must equal $a_{ij}a_{jk}$ or $a_{ij}a_{jk} = a_{ik}$ for the judgments to be consistent.

$$A = a_{ij}, \text{ when } a_{ij}a_{jk} = a_{ik}$$

This is called transitivity.

Axiom of transitivity:

$$\text{If } x_1 > x_2 \text{ and } x_2 > x_3 \Rightarrow x_1 > x_3$$

To calculate the approximation of consistency (CI), each cell of the first row of the matrix of comparisons $A = a_{ij}$ must first be multiplied by the column of priorities (p_i) and then divided by the value of the priority (p_1) of the corresponding row of the normalised matrix $A' = a'_{ij}$.

The same multiplication procedure is applied to the second row of the matrix $A = a_{ij}$. The resulting value is divided by the eigenvalue (p_2) of the second row and so on.

Finally, the maximum eigenvalue (λ_{max}) can be calculated by summing the resulting column of results (constancy measure) and forming the average (Saaty, 1986).

The closer λ_{max} is to the number of alternatives, the more a more consistent matrix of comparison arises.

Theoretically, a case is consistent if λ_{max} corresponds to the number of factors n . However, the real eigenvalues are always greater than the number of variables.

$$\begin{aligned} \lambda_{max} &\geq n \\ \lambda_{max} &= n \text{ In case of consistency} \\ \lambda_{max} &> n \text{ In case of inconsistency} \end{aligned}$$

Alonso and Lamata (2006) have computed a regression of the random indices and propose the formulation:

$$\lambda_{max} < n + 0.1(1.7699n - 4.3513)$$

If we now want to calculate the variance of the error in the estimation of a_{ij} , T. Saaty speaks of the consistency index (CI) for this value.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where n is the number of alternatives and λ_{max} is called the maximum eigenvalue. This index thus shows the extent of deviation from a perfectly consistent judgement ($\lambda_{max} = n$).

To determine the quality of the CI, it is compared with the random index (RI). The result is the so-called consistency ratio (CR).

$$CR = \frac{CI}{RI}$$

RI is the CI of a randomly generated reciprocal matrix on the scale 1 to 9.

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Figure 5: Random indices from (Saaty, 1977)

According to T. Saaty, a matrix of comparisons is considered consistent if the value of $CR \leq 0.1$.

Various calculations of RI exist (Alonso and Lamata, 2006) and there is also a controversial discussion about T. Saaty's range of $CR \leq 0.1$ (Apostolou and Hassel, 1993).

2.3 Group decision-making

The weighting of factors influencing dentists' office set-up decisions is a highly individual process. But a survey of representative group of dentists can find and evaluate trends and differences in this process.

For that purpose a questionnaire was designed that uses the Fundamental scale (Fig.3) to compare the selected local environment factors to be weighted and to record the respective favoured decision about the business type of practice (office) when setting up.

Every respondent (N=39) who took part in the pilot study on the empirical analysis of the influence of selected local environment factors on the founder's decision on the business type of practice had a licence to practise dentistry.

Generating a representative approximation for the group decision from the decisions of individuals is also a solvable problem according to Saaty's method.

For the methodology of the Analytic Hierarchy Process in group decision-making, the use of the **geometric mean** is appropriate:

$$P_i = \sqrt[n]{\prod_{j=1}^n a_{ij}}$$

The multiplicative error is generally assumed to be log normally distributed. Similarly, the additive error is assumed to be normally distributed. The geometric mean will minimise the sum of these errors (Saaty, 2012).

3. Results

The demonstration of the feasibility of the study design is given here based on the pilot study carried out.

3.1 Factor found in review

The systematic literature review led to five focus groups. These resulted in the extraction of nine local environmental factors relevant to the setting-up of a practice in dentistry.

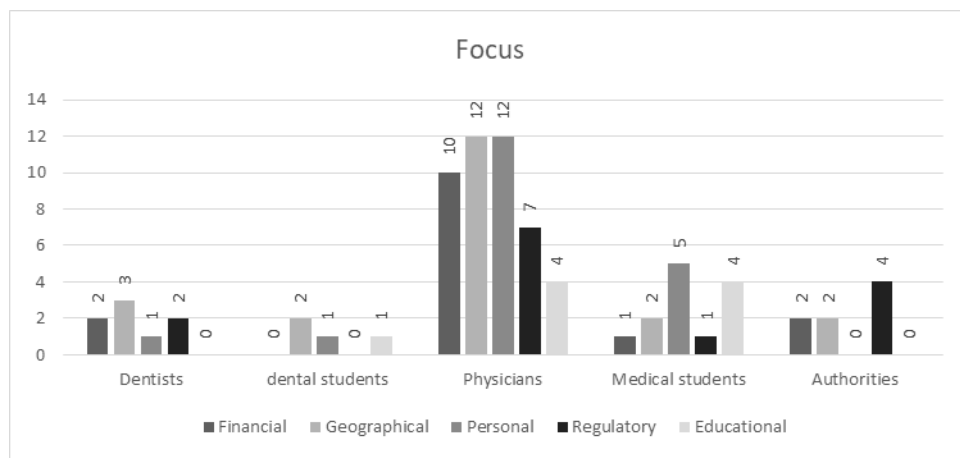


Figure 6: Selected Papers in review after focus

Selected Environmental Factors (SEF)	Publications
Financial conditions	Steinhäuser, 2011; Roick, 2012; Stengler, 2012; Steinhäuser, 2013; Scholz, 2015; Kittel, 2016; Vogt, 2016; Schmidt, 2017; Voltmer, 2017; Klingenberg und Köhler, 2019
Real income	Günther, 2010; Steinhäuser, 2011; Steinhäuser, 2013; Voltmer, 2017; Deutsch, 2020
Support Programms	Steinhäuser, 2011; Steinhäuser, 2013; Kittel, 2016; Vogt, 2016; Voltmer, 2017; Deutsch, 2020
Environment for the family	Günther, 2010; Steinhäuser, 2011; Roick, 2012; Stengler, 2012; Steinhäuser, 2013; Scholz, 2015; Kasch, 2016; Barth, 2017; Schmidt, 2017; Voltmer, 2017; Küpper, 2018
Quality of life in the private environment	Günther, 2010; Kiolbassa, 2011; Steinhäuser, 2011; Roick, 2012; Stengler, 2012; Steinhäuser, 2013; Scholz, 2015; Kasch, 2016; Vogt, 2016; Schmidt, 2017; Voltmer, 2017; Küpper, 2018
Professional cooperations	Günther, 2010; Steinhäuser, 2011; Roick, 2012; Stengler, 2012; Steinhäuser, 2013; Scholz, 2015; Kittel, 2016; Schmidt, 2017; Küpper, 2018
Location/region of practice	Steinhäuser, 2011; Steinhäuser, 2013; Deutsch, 2014; Kittel, 2016; van den Bussche 2016; Vogt, 2016; Voltmer, 2017; Mays, 2019; Kettler, 2019; Klingenberg und Köhler, 2019
Dentist Density	Steinhäuser, 2011; Steinhäuser, 2013; Scholz, 2015; Vogt, 2016; Voltmer, 2017; Kettler, 2019; Klingenberg und Köhler, 2019
Infrastructure	Steinhäuser, 2011; Kiolbassa, 2011; Steinhäuser, 2013; Scholz, 2015

Figure 7: Environmental factors found

The factors found in the literature review are the basis for the model of research.

3.2 Findings by using factors found in AHP

The analysis was carried out in four steps according to the methodology.

Step 1 (Hierarchy)

The overall goal is to decide on the satisfaction with a practice (level 1). The relevant criteria are the identified nine factors (level 2). The possible alternatives in this context are the different business types of a dental practice (level 3). The decision problem can thus be structured as shown in Figure 7.

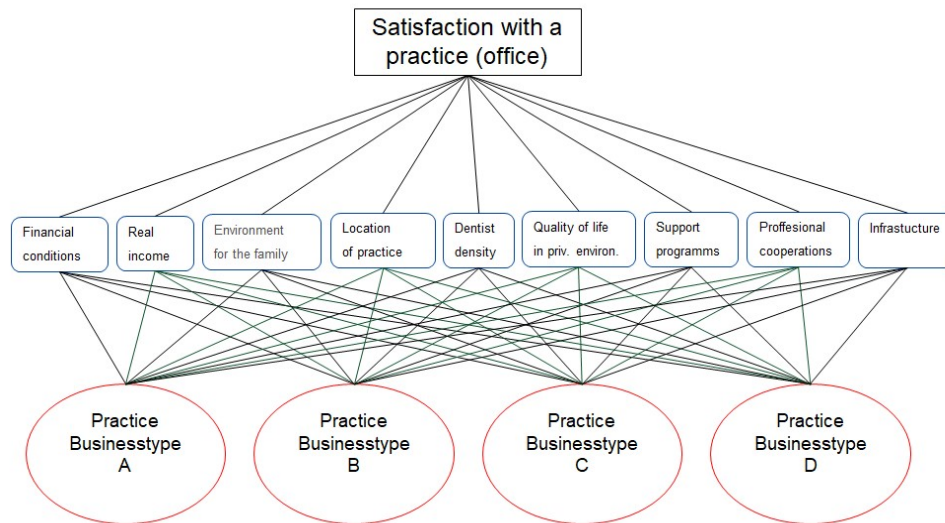


Figure 8: Hierarchy for the decision for a business type in dentistry

This step defines the levels according to the elaborate design of the AHP and determines the pair comparisons.

Step 2 (Pairwise comparison)

First, the number of comparisons can be calculated for the following nine factors:

$$\text{Number of pairwise comparison} = \frac{1}{2}n \times (n - 1)$$

$$\text{Pairwise comparison of criteria} = \frac{1}{2}9 \times (9 - 1) = 36$$

In order to make a group judgement, the judgements (N=39) were combined in Excel using the geometric mean (cf. 2.3.). This allowed a single judgement to be entered in each comparison.

The values are noted in the reciprocal matrix A:

$$A = (a_{ij})$$

$$a_{ij} = 1/a_{ji} \text{ or } a_{ij}a_{ji} = 1 \quad (a_{ij} > 0; i, j = 1, \dots, n; i, j \in A)$$

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{pmatrix} > 0 \Leftrightarrow a_{ij} > 0; i, j = 1, \dots, n$$

The pairwise comparison matrix of the AHP according to Saaty can be represented in the case at hand as follows:

$$A = \begin{bmatrix} 1 & \cdots & a_{19} \\ \vdots & \ddots & \vdots \\ a_{91} & \cdots & 1 \end{bmatrix}$$

Table 3: Reciprocal matrix

	A	B	C	D	E	F	G	H	I
A: Funding conditions	1								
B: Real income		1							
C: Support programmes			1						
D: Infrastructure				1					
E: Professional cooperations					1				
F: Dentist density						1			
G: Environment for the							1		
H: Quality of life in priv.								1	
I: Location of the practice									1

Table 4: Reciprocal matrix A with results of pilot study

	A	B	C	D	E	F	G	H	I
A: Funding conditions	1	1/3	1/2	1/3	2	1	1/5	1/5	1/3
B: Real income	3	1	1/2	1/2	2	2	1/3	1/4	1/3
C: Support programmes	2	2	1	1/3	1/2	1	1/3	1/4	1
D: Infrastructure	3	2	3	1	3	5	1/2	1/2	1
E: Professional cooperations	1/2	1/2	2	1/3	1	1	1/3	1/3	1
F: Dentist density	1	1/2	1	1/5	1	1	1/3	1/4	1
G: Environment for the family	5	3	3	2	3	3	1	1	2
H: Quality of life in priv environm.	5	4	4	2	3	4	1	1	4
I: Location of the practice	3	3	1	1	1	1	1/2	1/4	1

The matrix that emerges in this step shows numerically (see Fig.2) the pairwise weighting of the factors under investigation. These results are the foundation for the calculation of the normalized Eigenvectors.

Step 3 (Priority vector or Eigenvector)

In the third step, the weighting vectors are determined by an approximation procedure based on the matrices with the results of the pairwise comparisons (Saaty 2000).

(1) Sum the elements of each column j:

$$\sum_{i=1}^n a_{ij} \quad \forall i, j$$

Table 5: Reciprocal matrix A with sum of each column

	A	B	C	D	E	F	G	H	I
A: Funding conditions	1	1/3	½	1/3	2	1	1/5	1/5	1/3
B: Real income	3	1	½	1/2	2	2	1/3	1/4	1/3
C: Support programmes	2	2	1	1/3	1/2	1	1/3	1/4	1
D: Infrastructure	3	2	3	1	3	5	1/2	1/2	1
E: Professional cooperations	1/2	½	2	1/3	1	1	1/3	1/3	1
F: Dentist density	1	½	1	1/5	1	1	1/3	1/4	1
G: Environment for the family	5	3	3	2	3	3	1	1	2
H: Quality of life in priv. environm.	5	4	4	2	3	4	1	1	4
I: Location of the practice	3	3	1	1	1	1	1/2	1/4	1
Total:	23 1/2	16 1/3	16	7 5/7	16 1/2	19	4 1/2	4	11 2/3

(2) Divide each value by its column sum:

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}$$

Table 6: Matrix with derivative results from matrix A

	A	B	C	D	E	F	G	H	I	TOTAL
A:	0.0426	0.0204	0.0313	0.0433	0.1212	0.0526	0.0441	0.0496	0.0286	0.4336
B:	0.1277	0.0612	0.0313	0.0649	0.1212	0.1053	0.0735	0.0620	0.0286	0.6756
C:	0.0851	0.1224	0.0625	0.0433	0.0303	0.0526	0.0735	0.0620	0.0857	0.6175
D:	0.1277	0.1224	0.1875	0.1299	0.1818	0.2632	0.1103	0.1240	0.0857	1.3324
E:	0.0213	0.0306	0.1250	0.0433	0.0606	0.0526	0.0735	0.0826	0.0857	0.5753
F:	0.0426	0.0306	0.0625	0.0260	0.0606	0.0526	0.0735	0.0620	0.0857	0.4961
G:	0.2128	0.1837	0.1875	0.2597	0.1818	0.1579	0.2206	0.2479	0.1714	1.8233
H:	0.2128	0.2449	0.2500	0.2597	0.1818	0.2105	0.2206	0.2479	0.3429	2.1711
I:	0.1277	0.1837	0.0625	0.1299	0.0606	0.0526	0.1103	0.0620	0.0857	0.8749

The Normalised Eigenvector (p_i) can be calculated on this basis.

(3) Mean of row i:

$$p_i = \frac{\sum_{i=1}^n a'_{ij}}{n}$$

Table 7: Listing of the results the normalized Eigenvector

	TOTAL	p_i
A: Funding conditions	0.4336	0.0482
B: Real income	0.6756	0.0751
C: Support programmes	0.6175	0.0686
D: Infrastructure	1.3324	0.1480
E: Professional cooperations	0.5753	0.0639
F: Dentist density	0.4961	0.0551
G: Environment for the family	1.8233	0.2026
H: Quality of life in private environment	2.1711	0.2412
I: Location of the practice	0.8749	0.0972

These results can now be presented in order and weight:

Rank:	Environmental factor	Weight (%)
1.	Quality of life in private environment	24.12
2.	Environment for the family	20.26
3.	Infrastructure	14.80
4.	Location of the practice	9.72
5.	Real income	7.51
6.	Support programmes	6.86
7.	Professional cooperations	6.39
8.	Dentist density	5.51
9.	Funding conditions	4.82

Figure 9: Ranking of environmental factors resulting Pilot study

The Eigenvectors give a differentiated representation of the weighting of those multicriteria decision-making processes. The entirety of dentists surveyed in the pilot study weight quality of life in private environment (24.12%) as the most relevant factor. This is followed by environment for the family (20.26%), infrastructure (14.80%), location of the practice (9.72%), real income (7.51%), support programs (6.86%), professional cooperation's (6.39%), dentist density (5.51%), funding conditions (4.82%).

Step 4 (Consistency)

To check the consistency of the evaluated weights of the comparisons, the calculation of the consistency ratio (CR) is carried out:

$$A = a_{ij}, \text{ when } a_{ij}a_{jk} = a_{ik}$$

To calculate the consistency (CI), λ_{max} is required first. For this, each cell of the first row of the matrix of comparisons $A = a_{ij}$ must first be multiplied by the column of priorities (p_i) and then be divided by the value of the priority (p_1) of the corresponding row of the normalised matrix $A' = a'_{ij}$.

The same multiplication procedure is applied to the second row of the matrix $A = a_{ij}$. The resulting value is divided by the eigenvalue (p_2) of the second row and so on.

	λ_{max}
A	9.5682
B	9.8613
C	9.8613
D	9.6933
E	9.5803
F	9.5793
G	9.6915
H	9.7691
I	9.9190

Finally, λ_{max} can be calculated by summing the resulting column of results and taking the average (Saaty, 1986).

$$\lambda_{\text{max}} = \frac{\sum_{i=1}^n \lambda_{\text{max}}}{n}$$

$$= \frac{\lambda_{\text{max}}}{9.5682 \mid 9.8613 \mid 9.8613 \mid 9.6933 \mid 9.5803 \mid 9.5793 \mid 9.6915 \mid 9.7691 \mid 9.9190} = 9$$

$$\lambda_{\text{max}} = 9.7248$$

$$\lambda_{\text{max}} \geq n \Leftrightarrow 9.7248 \geq 9 \quad (\text{q.e.d.})$$

In the next step, the consistency index (CI) can be calculated:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$

$$CI = \frac{9.7248 - 9}{9 - 1} = 0.0906$$

To evaluate the quality of the CI, it is tested against the random index (RI). The result is the consistency ratio (CR).

$$CR = \frac{CI}{RI}$$

RI is the CI of a randomly generated reciprocal matrix on the scale 1 to 9 (Fig.4).

$$CR = \frac{CI}{RI} = \frac{0.0906}{1.46} = 0.0621$$

According to T. Saaty, a matrix of comparisons is considered consistent if the value of $CR \leq 0.1$.

$$CR \leq 0.1 \Leftrightarrow 0.0621 \leq 0.1 \quad (\text{q.e.d.})$$

Alternatively:

Alonso and Lamata (2006) have computed a regression of the random indices and propose the formulation:

$$\lambda_{max} < n + 0.1(1.7699n - 4.3513)$$

In this paper, nine criteria are compared. Consequently, it follows:

$$\lambda_{max} < 9 + 0.1(1.7699 \times 9 - 4.3513)$$

$$\lambda_{max} < 10.15778$$

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CI = \frac{10.15778 - 9}{9 - 1} = 0.1447225$$

$$CR = \frac{0.1447225}{1.46} = 0.099125$$

$$CR \leq 0.099125 \Leftrightarrow 0.0621 \leq 0.099125 \text{ (q.e.d.)}$$

$$\lambda_{max} = 9.7248$$

$$CI = 0.0906$$

$$RI = 1.4600$$

$$CR = 0.0621$$

As the consistency ratio meets the quality requirements, the AHP carried out is considered successful.

4. Discussion

This study analysed the decision whether a dentist sets up a dentistry and becomes self-employed or not. The dentist decision determinants have to be understood in order to foster the nationwide supply of dentist practices.

A statistical data evaluation based on postal loan figures and statistics from public institutions to assess spatially specific demand of dental services showed an increasingly unequal spatial distribution of the ratio of demand and supply for Germany (Schwendicke, 2016).

This data base helps to quantify spatial inequalities.

A cross-sectional study questioned dental students about the future work areas as dentist. Small and less populated areas were considered under 10% of respondents as a region of activity (Kettler, 2019).

This helps to understand that the inequalities will presumably increase.

To understand how physicians evaluate the general conditions for the establishment in rural areas Kittel et al. designed an AHP for 54 medical students (Kittel, 2016).

Katharina Schmidt et al. used an AHP to find out about how preferences differ between urban and rural physicians when choosing a location (Schmidt, 2017).

This will help to find out about the influence of the selected environmental factors on dentists' decision to establish a dental practice.

The AHP seems to be a suitable method for linking the factors identified and thus evaluating their influence on the decision to set up a dental practice.

AHP belongs to the classification of cardinal Multi-Attribute-Decision-Making (MADM). SMART, TOPSIS, ELECTRE, HRM and WP are also assigned to this category (for more information, see i.e. Sabaei, 2015). However, the listed methods of the Multi-Attribute Utility Theory do not belong to the methods of Group Decision Making.

Moreover, as a further advantage, the AHP also helps without considering problem complexity and uncertainty rate.

While the first three axioms can be fulfilled in the present case, axiom 4 is a point worth discussing for the current analysis. To fulfil the expectations (Axiom 4), all criteria and alternatives must be included in the design of the AHP. On closer inspection, heuristics are incomplete information, but they have an important meaning for the study carried out. By applying the heuristics, the presence of all criteria and alternatives can be considered implicitly. The problem seems therefore solvable.

The elaborated design appears clear and applicable. It should not be given sub-levels to be practically applicable. However, it can be extended to include other relevant criteria if necessary.

In the survey of 1,972 dental students in their final year of dental school, 53.1% stated that they would like to increase their quality of life during their time as dentists in training (Kettler, 2017). According to the pilot study conducted, the most important factors of the rank order derived are (1.) 'Quality of life in private environment' and (2.) 'Environment for the family'. This together corresponds with $p=0.4438$ to a large extent to soft location factors. This result confirms the findings of studies from general medicine (Kiolbassa, 2011; Steinhäuser, 2013; Kasch, 2016, Küpper, 2018).

These two soft location factors are followed by classic hard location factors: (3.) 'Infrastructure' and (4.) 'Location of practice'. Steinhäuser et al. likewise showed that a family-friendly environment, location and cooperation with colleagues were the three most important factors for general practitioners (Steinhäuser, 2011). Roik et al. came to a similar conclusion (Roik, 2012).

A positive influence of a transparent real income display on the career decision of medical students has already been presented (Deutsch, 2020). The question of what effect do financial and non-financial incentives have on the decision of young doctors to set up their own practice showed that, in addition to income, medical cooperation, professional opportunities for the partner, access to childcare, leisure activities, on-call duty play a decisive role (Günther, 2010). In this study, however, income is the strongest factor. Income in the present study is only in 5th place ($p=0.0751$) and seems to play a much smaller role. Thus, the factors (1.) 'Quality of life in private environment' and (2.) 'Environment for the family' together are 5x more important than income.

In this case the factors (6.) 'Support programmes', (7.) 'Professional cooperations', (8.) 'Dentist density' and (9.) 'Funding conditions' appear to have rather minor influence on the dentists' decision.

5. Conclusion

The nine criteria used are extracted from papers included in the literature review and should be considered as always in need of re-examination. Further research in this area on the categories of the selected factors seems advisable.

The method for weighting the factors relevant to setting up a dentistry provides a detailed breakdown of the various criteria. It can thus provide answers to the question of the influence on founders also in relation to the type of office or social characteristics.

The pilot study carried out proves that the chosen method of the AHP is an adequate approach to determine the influence of the factors relevant for the setting up of a dental business.

The issue of whether the decision on business types contributes to the weighting of the criteria or whether socio-demographic characteristics affect the ranking can henceforth be researched. In the next step, groups for the alternatives (business types) and socio-demographic features could be evaluated. This is done by differentiating the subjects according to additional criteria of the designed survey.

The selection of study participants for a representative result can now proceed.

Likewise, the consequences of these results for political actors and health care planning must be determined.

To secure full-coverage dental care offers, it seems to be meaningful to understand which decision-making factors are of most relevance for the suppliers' decision. The problem of allocation seems to be solvable only through a controlled and highly promising offer to the dental care suppliers. The more targeted an offer can be tailored, the more it can help to satisfy needs and thus help to prevent the shortage of dental health care services.

It is now a matter of implementing the described method and reviewing, expanding and deepening the present findings.

However, it remains an open question which other developments will influence not only the supply, but also the future demand. Here, public health care and health care research should always be vigilant in their research.

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