

MODELLING AND PROSPECTS OF THE AUDIENCE MEASUREMENT FOR OUTDOOR ADVERTISING BASED ON DATA COLLECTION USING GPS DEVICES (ELECTRONIC PASSIVE MEASUREMENT SYSTEM)

The paper describes how to integrate audience measurement and site visibility as the main research approaches in outdoor advertising research in a single concept. Details are given about how GPS is used on a large scale in Switzerland for mobility analysis and audience measurement. Furthermore, the development of a software solution that allows the integration of all mobility data and poster location information is introduced. Finally a model and its results are presented for the calculation of individual poster campaign coverage and for the calculation of the number of contacts generated by each billboard.

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Table of contents

1. INTRODUCTION	3
2. THE DIFFERENT RESEARCH APPROACHES	3
3. RESEARCH OBJECTIVE AND OBJECT	5
3.1. Research objective	5
3.2. Research object	5
4. METHODOLOGY	6
4.1. Geocells	6
4.2. Sample	7
4.3. Data collection	7
4.4. Mobility	8
5. PRACTICAL PROCEDURES	9
5.1. Processing of raw data	9
5.2. Way points	9
5.3. Tracks / Routing	9
6. VISIBILITY AREAS OF BILLBOARDS	10
6.1. Standard	10
6.2. Individualization	10
7. RELATION OF TRACKS AND VISIBILITY AREAS AND VISIBILITY ADJUSTMENT	11
7.1. Passages	11
7.2. SPR+ poster contact	14
7.3. Calculation example	14
8. MODELLING	14
8.1. Reach modelling with event history analysis	14
8.2. Extrapolation of reach	19
9. PLANNING TOOL SPR+ EXPERT	21
9.1. Three-stage performance model	21
9.2. Technology and architecture	22
9.3. SPR+ Expert Studio	22
9.4. SPR+ Expert Planning	23

1. INTRODUCTION

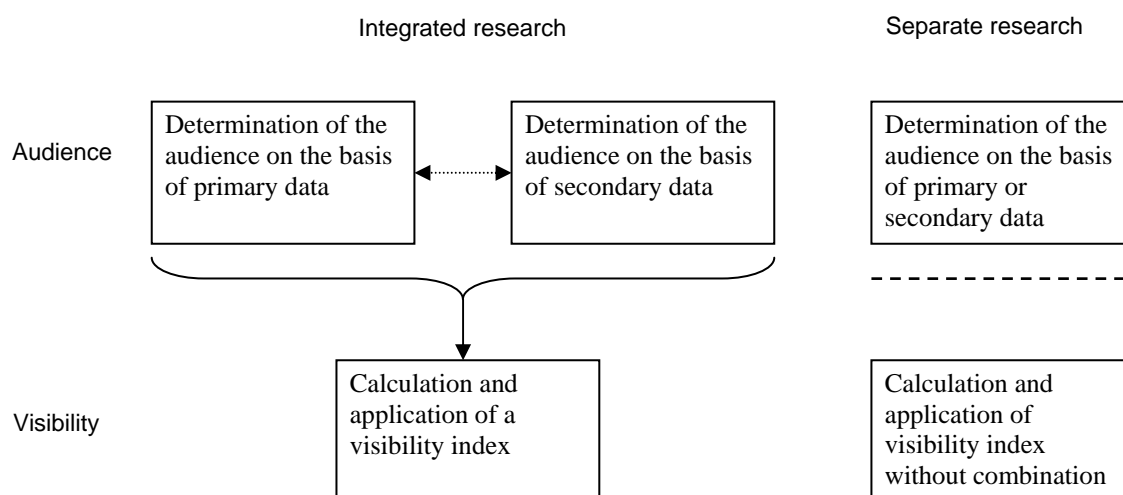
Since the late nineties, research in the field of outdoor advertising has undergone many developments for several reasons. First, new methods permitting audience calculation - such as the use of GPS - have made their appearance. Second, digital processing software for geographical data is being used both to position panels and to enable the performance of these panels to be calculated. Last but not least audience studies are being integrated with those of site visibility. This is an important step forward for the entire advertising medium.

Developed in the early 2000, the research concept applied in Switzerland takes on board all of these advances. After a brief description of the different routes taken for research in Europe and the choice made in Switzerland, this paper presents the different parts of the concept with the data gathered by means of the GPS system, calculation of contacts and weighting in the light of visibility criteria. A substantial part will then be devoted to modelling of all the data, to enable the performance of each advertising site to be calculated.

2. THE DIFFERENT RESEARCH APPROACHES

In a somewhat simplified manner, a distinction can be made between two types of study in the field of outdoor advertising. First, we have audience studies (based on the mobility of the people). Their purpose is to determine the coverage and the number of OTS for a set of panels. Because of their purpose, these studies enable a comparison to be made of the performance of poster sets or nets with a solution offered by a different medium (inter-media comparison). Then there are studies of site visibility. Because each particular panel has its own distinctive features (size, positioning in relation to the highway, height etc.), it is also important to determine the impact of these characteristics on the effective visibility of the sites. All of these studies seek essentially to determine the intrinsic performance of each site to enable them to be compared (classification or categorisation of the sites in an intra-media logic).

For several decades, these two types of study were conducted separately and as a rule the results were not integrated. For some years now, various methodological proposals have made their appearance with a specific view to their integration (see figure 1).

Fig. 1: Research approaches

The most comprehensive form of research is the one which takes on board the primary data gathered to calculate the audience and a visibility index applied to the data obtained. That is the case of the concept developed in Switzerland, but also for other integrated concepts. In the case of Switzerland, each conurbation is the subject of a specific study (mobility analysis). Data concerning movements of a sample of persons is gathered by the GPS receivers and the individual performance of each panel is weighted in light of criteria specific to the site. A second possibility allowing the integration of the two types of research consists of modelling the mobility behaviour of persons on the basis of secondary data (plotting an atlas of passage frequencies) followed by weighting as a function of the effective visibility of each site. That solution has been chosen in Germany. One third and final possibility is to refrain from integrating the two types of research. These are situations in which only one type of research is conducted autonomously. That is the case, for example, in France where many audience studies are performed but no site visibility criterion is applied to weight the results obtained.

It is worth pointing out here that none of the research approaches described above is better than another. The choice of an approach often depends on criteria which are not scientific: past experience, size of the country (the bigger the country the more convenient it is to work with secondary data), intensity of competition, cost of research, importance of the poster media in relation to other media, etc.

Our contribution presents the most comprehensive approach using primary data gathered to calculate the audience and specific criteria enabling an account to be taken of each panel's visibility.

3. RESEARCH OBJECTIVE AND OBJECT

3.1. Research objective

SPR+ investigates the media performance of poster campaigns and individual billboards on the basis of the individual contributions made by the poster sites involved in the campaign. This is achieved by assessing the number of visibility adjusted contacts generated by the individual poster sites among the population of a defined target area, broken down into various socio-demographic target groups.

3.2. Research object

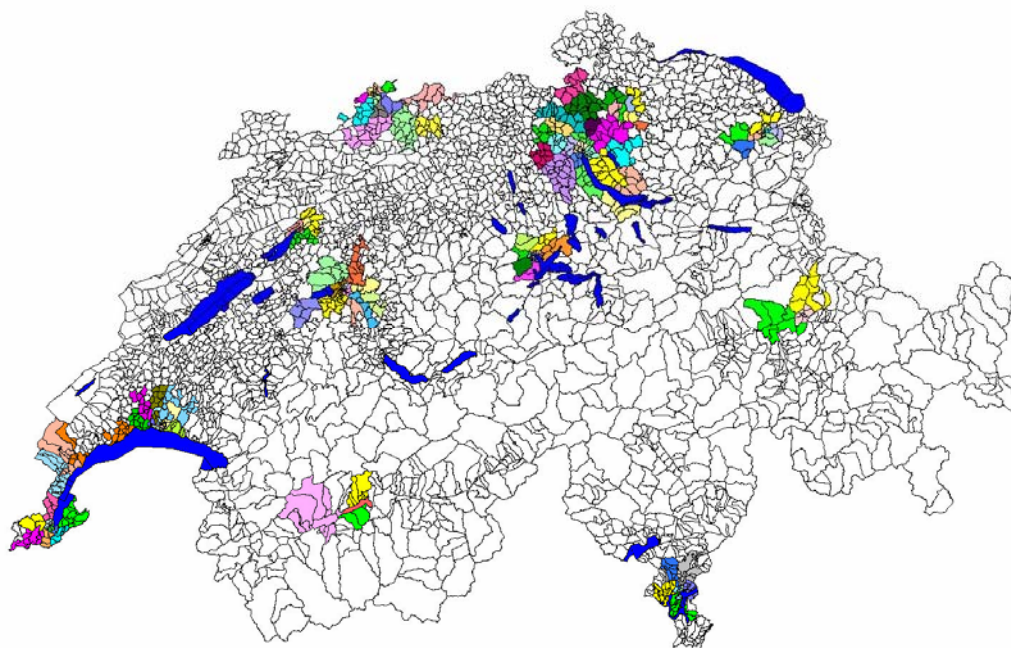
Two research objects are derived from the research objective.

Population of a conurbation

The study charts the mobility of the population residing in the conurbations under investigation. In the 55 conurbations live approximately 4.3 million people, out of which 2.9 million live in the GPS measured conurbations. For the conurbation borders and the population figures the definitions of the Swiss Federal Statistical Office (BfS) are applied, which come from the official national population count.

After a successful pilot study in the conurbation of Winterthur, further studies were conducted in the conurbations of Zürich, Geneva, Basel, Chur, Sierre, Sion, Biel, Chur, St. Gallen, Luzern, Bern and Lausanne (see figure 2).

Fig. 2: GPS measured conurbations



For all areas not covered by the field study, or for the planning of nationwide campaigns, a nationwide model is being implemented on the basis of mobility data and demographic parameters.

Also not covered are panels in objects such as parking facilities, shopping centers, and railway stations. For the research of object panels a pilot study of SPR+ started in 2007.

Poster panels/poster sites

In Switzerland the poster formats are relatively small and very dispersed across the conurbations, especially the inner cities. The formats F200 / F12 (1.9m² / 3.4m²) make up approximately 98% of the offer. The study provides performance data for approximately 60,000 panels of formats F12, F200, GF and F24 located in the various Swiss conurbations and documented on digital maps. The panels belong to APG, CCO and Star Plakat and make up over 99% of the Swiss ooh market.

The panels are digitalised on pixel maps provided by the Federal Office of Topography Switzerland (Swisstopo). As additional reference a road vector net, also provided from Swisstopo, is used. For the SPR+ study the following panel attributes are relevant: coordinates, azimuth, illumination and format.

4. METHODOLOGY

4.1. Geocells

To obtain representative results, not only the standard socio-demographic criteria of market research (age and gender) but also the mobility behaviour of the conurbation residents are taken into account. This criterion is important because in this way not only the population itself but also its mobility is representatively mirrored. For this purpose, SPR+ defines Geocells, i.e. geographic sectors within a conurbation whose residents display homogenous mobility behaviour relative to the core city. This information is obtained from the Swiss Federal Institute of Statistics. The sample of 90 (30 per age group) is then taken as a random quota CATI for each geographic cell and is defined for each community or district according to its population.

Fig. 3: Example of geocells of the Zürich conurbation



4.2. Sample

The selected random samples (approx. 10,000) are representative and depend on the size of the tested conurbations. The selection is based on age-group (15-29; 30-44; 45+) and gender (m/f) quota.

Table 1: Sample in the tested conurbations

Conurbation	Number of inhabitants 15+	Sample	Date of research
Winterthur	103'213	630	2002 - 2004
Zürich	918'676	1800	2004 - 2006
Geneva	390'672	1080	2005 - 2006
Basel	407'957	1080	2005 - 2006
Chur	55'018	270	2006
Sierre	69'626	270	2006
Sion	75'644	360	2006
Bienne	103'324	630	2006 - 2007
St.Gallen	122'276	720	2006 - 2007
Lucerne	164'690	810	2006 - 2007
Berne	298'757	1080	2007
Lausanne	260'206	1080	2007

4.3. Data collection

SPR+ records the routes of the persons in the random sample with a GPS device developed especially for this purpose (SPR+ Mobilitymeter).

For the latest generation of devices, cold-starting time is less than 30 seconds and operating time is at least 22 hours. The satellite signals are received by an especially

developed, highly sensitive processor. The handy device has an on/off switch that can be operated by the test person to maintain privacy.

Fig: 4 SPR+ Mobility meter



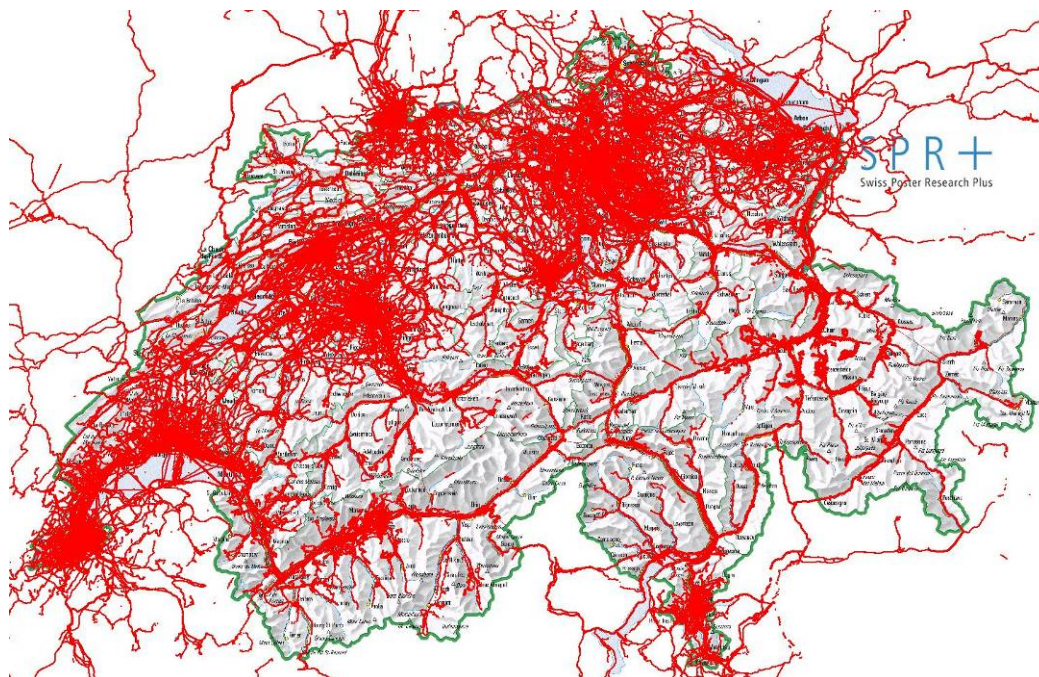
The persons wear the (cell-phone sized) Mobility meter for an entire week during which all out-of-home movements are recorded. It determines the current position of the test person at one-second intervals, recording the precise geographic coordinates, date, and time.

The research institute recruits test persons within the scope of screening interviews by telephone during which the socio-demographic characteristics of the test persons are determined (CATI). The Mobility meters are then handed out by the institute during a personal briefing. When the test persons return the devices personally, they are asked additional questions relevant to the study. Moreover, they are asked in writing about their media usage patterns and personal interests.

4.4. Mobility

The tracks of all with GPS measured test persons correspond to the mobility of the representative random sample. All in all the total length of measured mobility is more than 2.8 million kilometres.

Fig. 5: GPS measured mobility Switzerland



5. PRACTICAL PROCEDURES

5.1. Processing of raw data

The research institute transfers the recorded data directly to the SPR+ Geo-Information System. These are raw data which are individually validated for each person, i.e. checked for completeness and plausibility, and then processed further.

After acquisition, validation, and processing of the data received from all persons in a test conurbation, the special software calculates all contacts per person and poster panel, differentiated by socio-demographic parameters - for both poster networks and individual panels. The values obtained from the random sample can then be modelled to represent the universe of investigated areas.

5.2. Way points

The persons equipped with the Mobility meter record their out-of-home movements for an entire week. The advantage of GPS technology is that even micro-movements such as short detours to the newsstand or the laundry, typically forgotten during interviews, are recorded. The anonymized data are then electronically transferred to digital maps. In the database, first and last names are replaced by serial numbers. The measuring points, or fixes, are converted to tracks.



Fig. 6: GPS measured waypoints

5.3. Tracks / Routing

The SPR+ Geo-Information System software concatenates the individual route points into paths - called "tracks" - and calculates the speeds at which the test persons have moved through them. Gaps caused by passages below bridges, for instance, are automatically closed by routing in the same way as in vehicle navigation systems. Routing accounts for less than 5% of all tracks, and 99% of these have a length of less than 500 metres.



Fig. 7: GPS waypoints with track (blue)

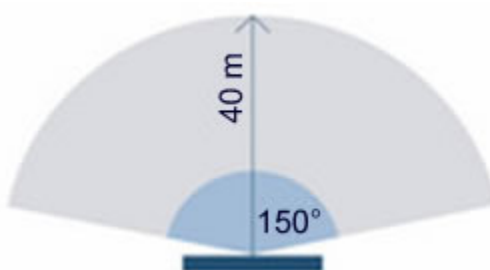
Fig. 8: Result track including routing under bridge

6. VISIBILITY AREAS OF BILLBOARDS

6.1. Standard

For each poster panel, an individual visibility area is defined, i.e. the geometric area from which the panel can be theoretically viewed. For this purpose, SPR+ only needs the panel's coordinates (x,y) and azimuth. The parameters defining the visibility area correspond to empirical values from other countries. Since the Swiss formats F200 (approx. 2 m²) and F12 (approx. 3.4 m²) are far smaller than the formats used in other countries and Swiss roads are much narrower, a maximum viewing distance of 40 meters was assumed. This is less than, e.g., in Anglo-Saxon countries where panels are much larger and posters are displayed along highways. The maximum opening angle is 150°.

Fig. 9: Standardized visibility area of a panel: schematic diagram



6.2. Individualization

The standardized visibility area is individualized objectively, neutrally, and automatically by GIS intersection with building vectors. In Switzerland, these vectors are geocoded by Swisstopo, the official cartographic authority. As a result, a value for the individualized 100% visibility area is available for each panel. Viewing obstacles and dead angles are punched out like cookies from dough.

Step 1: Create panel visibility areas**Step 2: Overlay building vectors****Step 3: Intersect visibility areas / building vectors****4: Result: Individualized visibility areas**

7. RELATION OF TRACKS AND VISIBILITY AREAS AND VISIBILITY ADJUSTMENT

7.1. Passages

At this stage the SPR+ Geo-Information System contains the geocoded data of all panels with individualized billboard visibility areas and the test persons' tracks from the GPS sample. Finally, the system computes the relationship between the tracks and the visibility areas, yielding passages as a result. Each passage is then weighted on the basis of the SPR+ weighting criteria, and the final result of this operation is the poster contact.

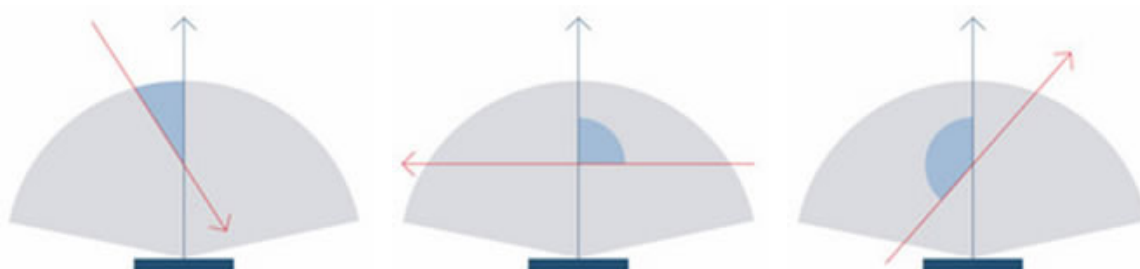
Fig 10: Example passage (blue) and visibility area (green)



Not every passage through the visibility area of a poster panel generates a poster contact. SPR+ accounts for this fact by subjecting all passages to four weighting criteria: passage angle, passage speed, time of day, clutter (quantity of panels per poster site).

Passage angle

Magnitude of passage angle and effect on the poster contact



Frontal poster contact: $<45^\circ$ Parallel poster contact: $45^\circ-110^\circ$ No poster contact: $>110^\circ$

The passage angle is the angle between the direction of the subject's movement and the viewing direction of a poster panel. A passage angle of 0° means that the subject's direction of movement and the viewing direction of the panel coincide, i.e. person and panel meet frontally. The passage is weighted depending on the passage angle:

- Angle less than 45° : frontal contact
- Angle between 45° and 110° : parallel contact
- Angle greater than 110° : no contact

Passage speed

The passage speed is the speed at which a test person moves through the visibility area of a poster site. The passage is weighted depending on the passage speed:



- Speed less than or equal to 10 km/h: «Pedestrian contact» with weighting factor 1
- Speed greater than 10 km/h: Weighting factor 1 in case of frontal passage, weighting factor 0.3 in case of parallel passage

Time of day

Passages during the night when panels are not illuminated generate no poster contacts. SPR+ distinguishes between:

- Illuminated panels: Weighting factor 1 (all passages between midnight and midnight)
- Non-illuminated panels: Weighting factor 1 (passages between 6 a.m. and 8 p.m.) and weighting factor 0 (passages between 8 p.m. and 6 a.m. = no contact)

Clutter (number of panels per poster site)

In many locations, panels are arranged in small groups referred to as poster sites. The panels at such sites share a common visibility area and thus compete with each other. Depending on the number of panels per site/location, passages are weighted differently.



7.2. SPR+ poster contact

The SPR+ poster contact is the weighted passage through the individualized visibility area of a poster panel. SPR+ poster contacts are personalized. Poster viewers are mobile persons generating one or several contacts with the poster advertising medium in a public space. The poster audience represents the sum of all mobile persons generating one or several contacts with the poster advertising medium in a public space.

7.3. Calculation example

A parallel passage of a car driver at daytime with a speed of more than 10 km/h through the visibility area of a panel sharing a site with three other panels yields a poster contact of $0.15 = 1 \text{ passage} \times 0.3 \text{ (for parallel at } >10 \text{ km/h)} \times 0.5 \text{ (for clutter with 3 adjacent panels)}$. If several contacts are generated within a period of 5 minutes, SPR+ counts only the passage with the greatest contact value. This avoids incorrect multiple counts, e.g. when the person walks back and forth at a tram stop.

The SPR+ poster contact is a measure of contact probability. Whether a contact is actually generated depends not only on the site characteristics and the person's behaviour but also - and significantly - on the creative design of the posters.

8. MODELLING

One central criterion for the rating of poster campaigns is reach. Poster reach states the percentage of population that passes a selection of posters within a previously defined interval of time. This section explains the technique which is used to determine reach for a given campaign based on the obtained poster contacts of test persons as described in the previous section. The first subsection introduces event history analysis which provides, amongst others, basic methods for data analysis under censoring. The second subsection treats the extrapolation for cities without GPS measurements.

8.1. Reach modelling with event history analysis

Reach is a continuous function over time and therefore demands trajectory data of consecutive days for each test person. However, although the mobility survey has been conducted with great care, the data set contains incomplete GPS records due to the forgetfulness of people or technical defects. Clearly, the toleration of missing days in the GPS recordings leads to an underestimation of reach and gross contacts. The missing data cannot simply be replaced as the mobile behaviour during these periods is completely unknown. Also, the deletion of all test persons with incomplete records forms no acceptable alternative, because the data set would be substantially reduced (which might also change the sample distribution) and many reliable GPS measurements would be lost.

Instead, we selected a modelling technique from the area of event history analysis which treats absent data explicitly.

Event history analysis (also: survival analysis) [11] is a branch of statistics that investigates the probability of some event or the amount of time until a specific event occurs. It is usually applied in clinical studies and quality control where an event denotes, for example, the occurrence of some disease or the failure of a device. Kaplan-Meier is a method from event history analysis which allows for censored data. It calculates the probability that some event does not occur (i.e. the person / object of interest “survives”) in a given period of time. For example, Kaplan-Meier can be used to calculate the life expectancy after a cancer treatment. Naturally, people enter a medical study at different points in time and therefore possess differing lengths of participation. Furthermore, people can drop out of the study when moving into another city or dying from a different cause. More formally, the random variable T represents the survival time of a person or object.

The function

$$S(t) = P(T > t)$$

is called the survival function and states the probability that the specified event occurs later than some time t . For a given data set, Kaplan-Meier analyses at times t_i events occur (with $t_0 = 0$) and determines the following variables

- r_i – number of persons / objects at risk at time t_i ,
- d_i – number of events at time t_i ,
- c_i – number of censored persons / objects between t_i and t_{i+1} .

The number of persons / objects at risk at a time t_{i+1} consists of all persons / objects that survive time point t_i and have not been censored, i.e. $r_{i+1} = r_i - d_i - c_i$. Kaplan-Meier adapts to differing sample sizes by calculating conditional probabilities between two consecutive events. Persons or objects that drop out of the study between two events are assumed to survive until the next event occurs and are then censored. The conditional probability p_i to survive time point t_i given that t_{i-1} has been survived is calculated as

$$p_i = P(T > t_i | T > t_{i-1}) = \frac{r_i - d_i}{r_i}.$$

Given the conditional probabilities p_i , the total probability to survive some time point t_k is

$$S(t_k) = P(T > t_k) = \prod_{i=1}^k p_i.$$

Fig. 11: Concepts and application of event history analysis

Survival Analysis <ul style="list-style-type: none"> • objects • events • censoring 	Medicine / Engineering <ul style="list-style-type: none"> • patients / techn. devices • death / defect • drop out of patients / devices 	Outdoor Advertisement <ul style="list-style-type: none"> • test persons • first poster contact • persons with less than 7 valid measurement days
Statistical Quantities <ul style="list-style-type: none"> • random variable T • cumulative distribution function F(t) • survival function S(t) • hazard function h(t) • cumulative hazard function H(t) 	Formula <ul style="list-style-type: none"> $T \sim (0, \infty)$ $F(t) = P(T \leq t)$ $S(t) = P(T > t) = 1 - F(t)$ $h(t) = \lim_{\Delta t \rightarrow 0} P(t \leq T < t + \Delta t T \geq t) / \Delta t$ $H(t) = \int_0^t h(s) ds$ 	Interpretation <ul style="list-style-type: none"> • time until first poster contact • probability of a test person to have a poster contact before t • probability of a test person to have a poster contact after t • contact probability at t given a poster has not been seen • cumulated contact probability

The analogy to modelling poster reach is straightforward. An event denotes the first contact of a person with a given campaign. However, in order to apply the described method, all missing days of a test person need to be moved to the end of the surveying period. A person is then censored if no further tracks are available. We hereby assume that all measurement days are of equal value and can be permuted without impact. So far, S(t) states the probability that people in the data sample will not have any contact with the campaign. Consequently, the reach of a campaign is given by the probability of the complimentary event

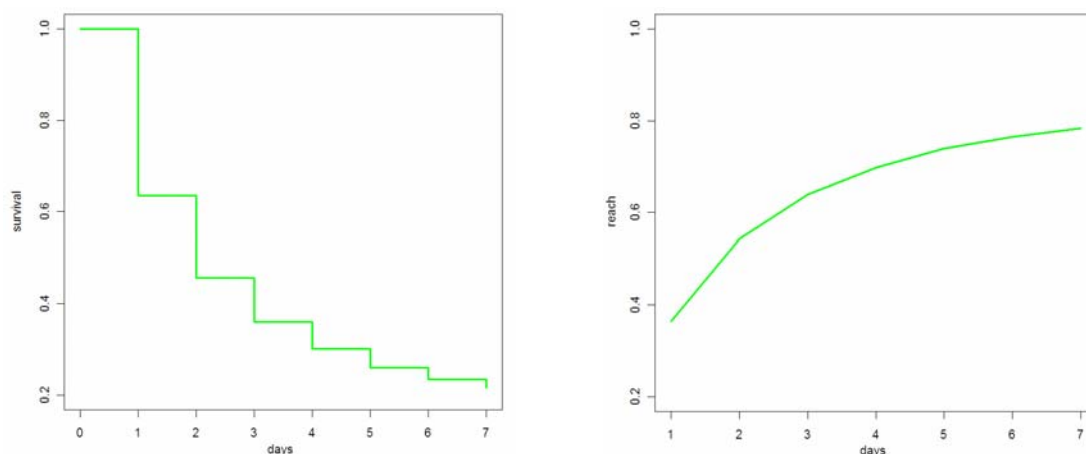
$$F(t) = P(T \leq t) = 1 - S(t).$$

Fig. 11 summarises the concepts of event history analysis and its application in to calculate reach in outdoor advertisement.

Fig. 12 shows the survival and reach of a poster campaign in the conurbation Winterthur. On the left, the survival is depicted as step-function. Each time a first poster contact occurs, the survival probability decreases. On the right, the corresponding reach is shown with linear interpolation over a period of 7 days.

The surveyed test persons form a representative sample of the universe. Therefore, the reach estimated from the sample tracks is an unbiased estimate of the reach in the population. According to the selection of test persons, for example from a specific area or age group, the reach of different target audiences can be determined.

Fig. 12: Survival and reach of a poster campaign in Winterthur, Switzerland



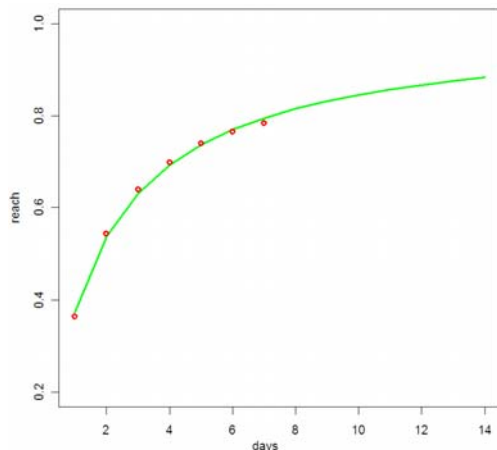
8.2. Extrapolation of reach

The inference of reach in case of insufficient GPS measurements is a challenging research task. As described in Section 3, GPS surveys have been conducted in 12 conurbations of Switzerland for a period of mainly 7 days. This setup necessitates the extrapolation of reach in two ways. First, using the Kaplan-Meier method as described in the previous section, reach can only be determined for about 7 days. However, the usual periods for poster campaigns range between 7 and 21 days. Second, the conurbations in the survey contain about 73% of all posters in Switzerland. For the remaining poster sites, no mobility data is available.

For the extrapolation of reach beyond the surveying period, we combine two different extrapolation techniques. The first technique utilizes the reach of one week to fit a log-linear function and subsequently extrapolates values for longer periods. The second technique relies on the assumption of weekly periodic mobility patterns and replicates mobile behaviour accordingly. Both techniques are interweaved according to the stability of available data.

Fig. **13** shows an extrapolation of reach over a period of 14 days for the same poster campaign as above. The red circles mark the reach as obtained from Kaplan-Meier analysis, which have been used to fit the log-linear model.

Fig. 13: Extrapolation of reach over a period of 14 days



The extrapolation for areas without GPS measurements is a great challenge. Neither GPS data nor other mobility information, as for example traffic frequencies, are available. In addition, individual site characteristics which affect the weight of a passage need to be taken into account for the calculation of poster reach. The extrapolation method therefore consists of three separate steps. First, the traffic behaviour at the poster locations of interest is inferred. Second, the passages are scaled according to individual poster characteristics. Finally, the reach of a campaign with similar contact distribution is assigned to the campaign of interest. In the first step, various location attributes, as the type of street, type and number of nearby points of interest or the size of population, define a similarity measure by which poster passages are extrapolated. For the next step, a scaling factor which transforms passages into poster contacts is applied. The factor depends on individual poster characteristics and is determined based on evaluations in GPS cities. The final assignment of poster reach depends again on a similarity measure, which is defined on the contact distribution of the campaign of interest. – The extrapolation method thus accounts for general traffic characteristics, yet allows for individual features of poster campaigns.

9. PLANNING TOOL SPR+ EXPERT

9.1. Three-stage performance model

- Total performance in a defined universe (classical performance)
- Performance in the selected target areas (classical performance)
- Performance contribution per panel (contact value)

In addition, the users are offered a method to calculate the performance universally and per target area on the basis of a selected contact class. For example, they will be able to document the campaign performance for those target persons who have had at least a number of weighted contacts with the campaign whose sum amounts to $(0.15+0.5+\dots+0.8=15)$. This performance record is referred to as Coverage Contact Class (CCC).

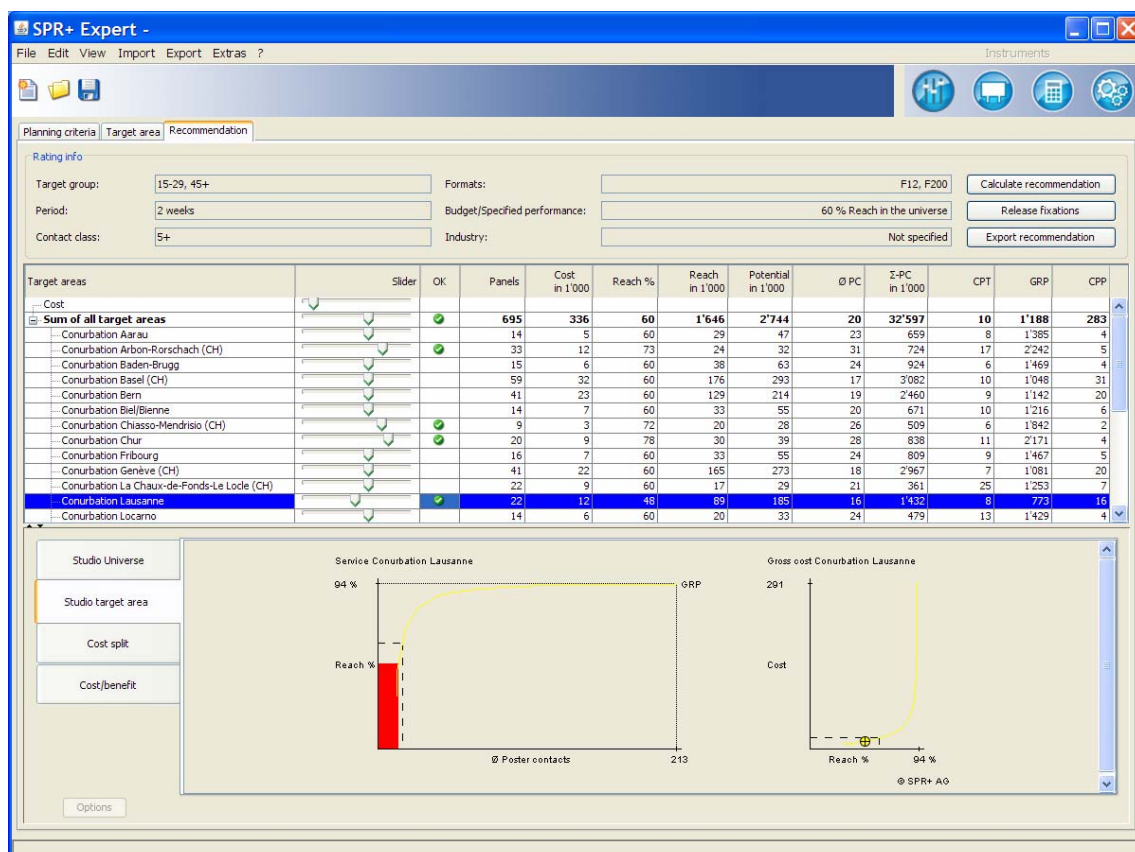
9.2. Technology and architecture

SPR+ Expert is a web-based Java application running on all popular operating systems. This architecture enables clear-cut data separation. The research data are maintained at SPR+ whereas the sensitive campaign data are stored exclusively on the customer's hardware as local files. Additionally, this modern architecture minimizes the user's administrative requirements because software updates can be implemented on the SPR+ server.

9.3. SPR+ Expert Studio

The first step to planning a poster campaign is the development of an overall strategy which includes, among other things, the selection of the medium or, in case of a media mix, the budget split. SPR+ Studio assists customers and their media planners both in this first step and in the subsequent definition of the intramedia poster strategy. At this stage, the selection of the target areas is usually still open and specific poster panels have not yet been determined. Accordingly, SPR+ Studio does not use specific performance values per panel but rather the derived panel averages per community. Depending on the planning criteria entered (target group, budget, performance requirements, and format), SPR+ Studio generates recommendations with respect to target areas and the necessary number of panels per target area.

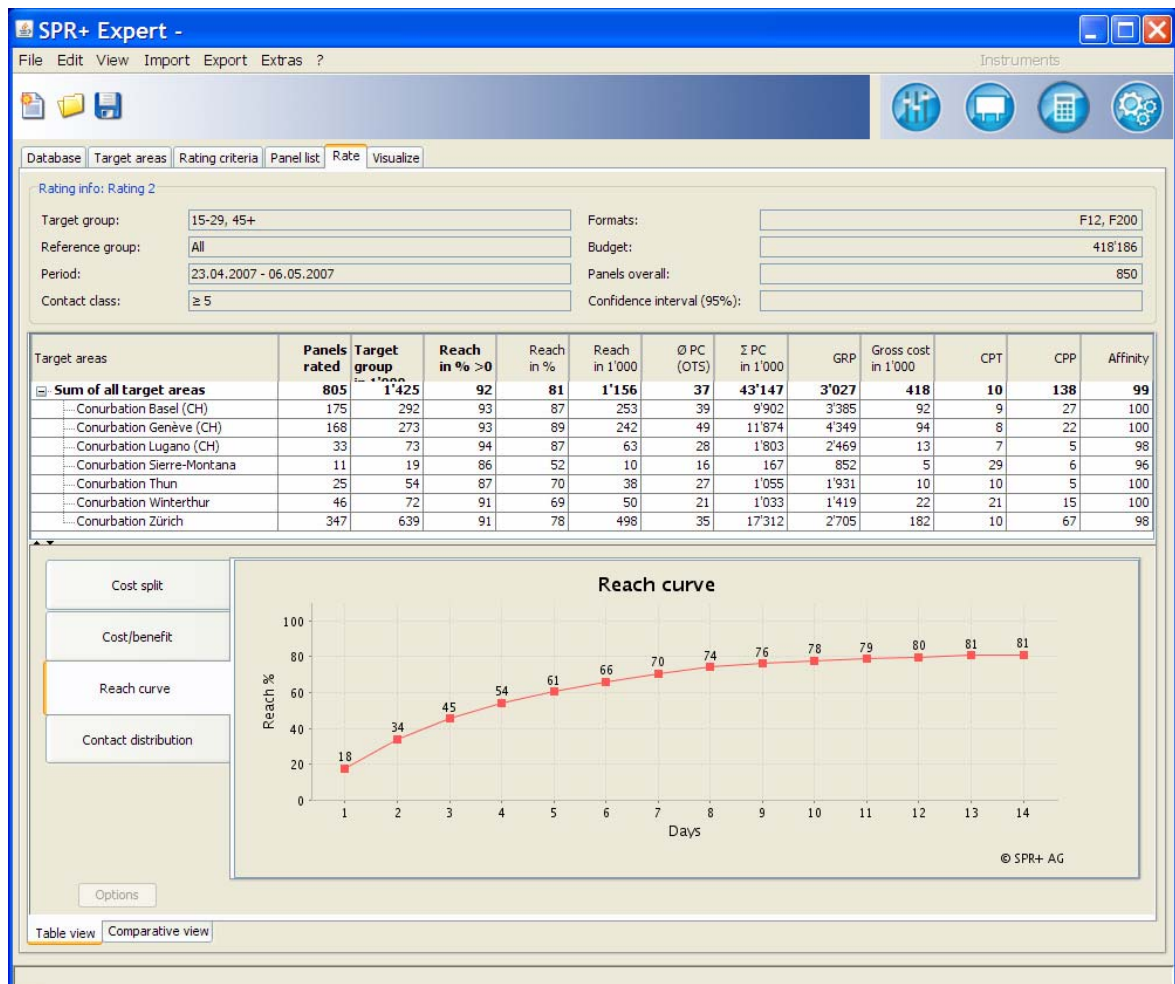
Fig 14: SPR+ Expert Studio recommendation



9.4. SPR+ Expert Planning

This module is the core component of SPR+ Expert. It supports the detailed planning of poster campaigns. After receipt of the quotes from all providers by e-mail, these quotes - including full detail information per panel - can be imported into SPR+ Planning. The tool then generates a convenient table of all panels. The table can be further processed by the user, i.e. sorted and filtered by formats, costs, panel characteristics, keywords, etc. When detail planning is complete and the user has defined the evaluation criteria, he can trigger the evaluation process for target-group-based performance calculation and, depending on campaign size, obtain within minutes the performance data per panel and the classical performance values for the total campaign involving several providers.

Fig 15: SPR+ Expert Planning poster campaign rate



SPR+ Planning offers the flexibility to deactivate or delete individual volume panels or products from the evaluation or to add newly imported quotes to the planning process at any time. Additional features are:

- Automatic generation of Excel display schedules (including cost, performance, and product overviews) based on various aggregation levels and individual requirements
- Timeline representation of the entire campaign
- Various export capabilities
- Evaluation comparisons
- Diagrams (e.g. reach progression) and schematic map tools
- Geographic Information System (GIS) with POI and POS