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CRITERIA FOR EVALUATING THE EFFECTIVENESS OF PASSENGER INFORMATION DISPLAYS

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A high percentage of Romanian population lives in urban environment. Public transport services are critical for citizen mobility in most of the major Romanian cities. An effective journey planning depends on accurate information regarding the arrival and departure of public transportation vehicles / trains. The main public access to real-time information is based on passenger information displays. The paper presents the results of the research carried out in the field of information visualization, which were applied to passenger information displays. During the research the categories of information to be displayed and their informational characteristics were identified and described. The main objective of the research was to define the criteria for assessment of the visual representation of these categories of information, starting from the questioning the visibility, legibility and readability of the display content. The defined assessment criteria are used to develop a framework for evaluating of existing passenger information displays and improving the performance level of the human-display joint cognitive system.

Keywords: information visualization, passenger information display, urban mobility.

1. Introduction

According to year 2013 statistics, 54.91% of Romanian population lives in urban environment: municipalities and towns. Public transport services are critical for citizen mobility in most of the 24 Romanian municipalities having more than 100,000 citizens and representing 7.5% of Romanian population. An effective journey planning depends on obtaining accurate information regarding the planned and real-time arrival and departure time of public transportation vehicles / trains. The main public access of citizens to real-time information is based on passenger information displays (PIDs) with dynamic content.

The advantage of PID uniformity is that passengers will respond to PID content in a manner consistent with their previous experiences with that type of PID and transport scenario. If similar transport scenarios are reflected in PID

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content in a consistent manner, the passengers will respond in a consistent and predictable manner. [1]

The most critical problem of the PIDs is the fact that the uniformity level in PID designing and manufacturing is completely absent, compared with traffic signs situation, as example. There are no consistent standards, ordinances, codes, rules or guides regarding the manner of design, construction and installation of PIDs at Bucharest metropolitan level.

PIDs are not efficient if they do not provide the necessary information for a specific category of passengers at a defined moment and place. PID deficiencies include the following [2] :

- Poor placement of PIDs (low visibility) ;
- Too many neighboring signs masking the content of the PID (visual clatter and low conspicuity) ;
- Inadequate legibility distance ;
- Too less or too much information ;
- Poor coding of content in text and symbols.

An adequate design of PIDs requires an interdisciplinary professional expertise. The paper presents the results of the research carried out in the field of information visualization, which were applied to passenger information displays. During a initial research phase, the main evaluation criteria applicable to PIDs were identified and defined.

Significant contributions to the fields of ergonomics and anthropometrics were brought by H. Dreyfuss [3] and A. R. Tilley [4], including anthropometric data related to the human visual fields. A. H. Wertheim [5] described in detail the visual conspicuity features and introduced a standard of quantitative measure, based on the concept of lateral masking. C. A. Rothkopf. D. H. Ballard and M. H. Hayhoe [6] analyze the importance of salience and task objectives on human gaze movement. Comprehensive guides for good practice related to sign visibility and sign legibility were elaborated by a research team in Pennsylvania State University and published by US Sign Council [7] [8].

The PID evaluation criteria intend to evaluate the degree to which a PID will perform its intended purpose, regardless of any particular / given situation : providing real-time passenger information. The paper does not provide the nominal values for any measurable parameter involved in the evaluation process.

2. Urban transport information and PID content

The urban transport network has to improve its service-oriented feature and to provide high quality information to passengers. The PID has to take into consideration passenger expectations and the integration of the urban transport system in the overall urban environment **[9]**.

The ability of passengers to read and interpret information differs with age, education and experience. In many urban areas multi-lingual information is required; the use of non-textual information is recommended.

Fig. 1 - Passenger Information Displays in Copenhagen (personal photos)

Public transportation passengers need various categories of information during journey planning and making. An example of dynamic PID content including the main information categories is illustrated in Fig. 1. The information requirements depend on a wide variety of factors. For example, the most important information categories which have to be displayed on dynamic PIDs are [10] :

- Line number and destination end station ;
- Possible connections for interchange ;
- Scheduled or real-time (estimated) information :
    - Timetable, arrival and departure time ;
    - Service disruption, cause and duration ;
    - Train composition.

3. Visibility and conspicuity

Designing a good PID requires knowing the space region from where it has to be viewed by the passengers. The designer has to define where the PID will be located, where the passengers will be and start to observe the PID and what actions will be performed by the passengers as response to the PID content.

The visibility of a PID allows for PID visual detection by the passengers at a given distance. Visibility is considered from an objective perspective and does not take into account the passenger features. Also, the visibility does not consider if the next sensorial-perceptual phase is successfully completed. The performance of the PID detection process can be measured in terms of PID detection speed $v_d(PID)$ or, reversely, PID detection time, $\tau_d(PID)$.

The PID visibility depends on a series of factors related to the environment in which is installed: overall size of the PID (target size), PID position in space and time (if the content is sequentially displayed), luminance contrast between PID and the background (external contrast). The PID visual blockage or overlapping of other physical elements on the PID strongly impairs its visibility [7].

A good measure of visibility is the amount of effort required to be spent by the passenger to include the PID within the main visual field. The effort value depends on the angular amplitude of the passenger eyes, head and body movements.

For a given PID position P_{PID} and a given passenger station point P_{PSP}, we define the visibility index as a measure of visibility. The visibility index dependencies are expressed in the following relationship :

$$I_{visibility}(P_{PID}, P_{PSP}) = I_v\left(k_{blockage}, e_{eyes}, e_{head}, e_{body}\right) \quad (1)$$

.where $k_{blockage}$ is the PID blockage coefficient expressing the percentages of the PID overlapped by another object, and $e_{eyes}, e_{head}, e_{body}$ are the effort values described above.

A relationship that defines the visibility index is :

$$I_{visibility}(P_{PID}, P_{PSP}) = \left(1 - k_{blockage}\right)\left(1 - \frac{e_{eyes} + e_{head} + e_{body}}{e_{total}^{max}}\right) \quad (2)$$

.where e_{total}^{max} is the maximum total value of effort that can be spent by the passenger for including the PID into the main visual field. When the PID is fully visible without any passenger effort, $k_{blockage} = 0$ and $e_{eyes} = e_{head} = e_{body} = 0$, and the visibility index value is maximum $I_{visibility} = 1$.

An important feature of the PID is conspicuity, which is related to the capacity of the passenger to notice and be aware of PID existence. PID conspicuity is the result of the passenger ability to differentiate between PID and its background. Similar to visibility, conspicuity is considered from an objective perspective, taking into account the passenger position relative to PID. A high level of conspicuity reduces the PID detection / search time $\tau_d(PID)$.

A systematic analysis of the conspicuity has to consider the position of the PID within the overall visual landscape accessible to the passenger. The tri-dimensional spatial position of the PID has to be analyzed both in relation to passenger position and sight direction. Before questioning the PID conspicuity level, the PID has to have a maximum value of visibility index, i.e. has to be situated in the passenger main visual field. The PID spatial features has a strong influence upon the passenger pre-attentional effort value which is required in order to detect the PID presence without involving any cognitive process :

- The distance between PID position and passenger position ;
- The PID plane obliquity related to the passenger sight direction ;
- The PID 2D position in the plane which is normal to the passenger sight direction ;

PID is placed in a visual landscape full of various visual stimuli. The conspicuity of a PID depends on the total number of salient targets detectable by the passenger in his/her visual field during pre-attentional processes.

From the attractiveness perspective, the PID conspicuity depends on several factors : number of active distractors or salient targets, their position and grouping. The distractors active in the visual landscape of the passenger can be classified by various features : spatial, luminance, color and texture distractors. An active distractor exhibits a strong dissimilarity against its background. An example of PID conspicuity based on color contrast attractiveness / dissimilarity is illustrated in Fig. 2.

Fig. 2 – Visual conspicuity based on color contrast attractiveness (personal photo)

The PID attractiveness or saliency related to the neighboring objects can be examined from several perspectives, based on dissimilarity of feature values:

- The size attractiveness – the PID 2D dimensions dissimilarity to the size of the neighboring objects ; also the PID area dissimilarity to the area of the neighboring objects ;
- The luminance / color attractiveness – the PID illumination dissimilarity to the background illumination, which can be measured in terms of luminance contrast and chrominance contrast ;
- The shape attractiveness – the PID shape contour dissimilarity to the neighboring contours ;
- The spatial frequency attractiveness – the PID content spatial frequency (pattern and texture) dissimilarity to the background.

A good measure of conspicuity has to consider the relationship between all triad members : passenger, environment, PID. The conspicuity index relationship expresses the dependencies :

$$I_{conspicuity}(P_{PID}, P_{PSP}) = I_c\left(n_{distractors}, k_{group}, \left(d_{sz}^i, d_{lc}^i, d_{sh}^i, d_{sf}^i\right)\right) \quad (3)$$

.where $n_{distractors}$ is the total number of distractors, k_{group} is the grouping factor and $d_{sz}^{i}, d_{lc}^{i}, d_{sh}^{i}, d_{sf}^{i}$ are the dissimilarities between feature values of PID and all the other salient targets. The color dissimilarity can be expressed as a distance in the CIE 1931 color space and the luminance dissimilarity can be expressed as Michelson contrast, for example.

An effective method of increasing the value of visual separation level between the PID and the visual landscape and visual de-cluttering is the use of PID border / contour. For an optimum conspicuity, the PID border has to have the same width and luminance as the letter stroke. The border shape is usually rectangular with rounded corners.

4. Legibility and readability

The passenger final response to a PID is an action, which is chosen according to the PID content and the level of understanding its meaning. The semantic content of a PID can be extracted by one simple reading – in case of previously known words/symbols – or only after repeated readings.

PID legibility refers to the capacity of the passenger to detect all the PID elements (letters, words, symbols and icons) which carry the semantic content. Legibility is related to the visual separation level between the functional picture elements of the PID. Legibility depends on the passenger ability to detect the contour/shape of the elements.

On the other hand, PID readability is the ability of the joint cognitive system formed of the passenger and the PID to extract the semantic content of the elements and to successfully finalize the comprehension of all PID messages, with a minimum error rate. Readability is the ability of the passenger to understand the meaning of the text and symbols displayed in a PID.

While the legibility is predominantly objective, the readability depends mostly on the cognitive ability of the passenger to map the PID elements back to the original information encoded into text and symbols.

The legibility of the text messages or text strings depends on the following physical features of the PID [8]:

- Letter typeface / font (serif or sans-serif) – less legible typefaces require increasing the letter size ;
- Letter case (uppercase or lowercase) ;
- Letter proportion / form factor (width : height) and letter size ;
- Stroke width to letter height ratio ;
- Letter spacing, word / symbol spacing and interline spacing ;
- The PID plane obliquity related to the passenger sight direction.

The legibility strongly depends on the luminance and color contrast level between the picture elements and the PID background (internal contrast). A good measure of legibility has to consider the relationship between all triad members : passenger, environment, PID. The legibility index relationship expresses the above mentioned dependencies :

$$I_{legibility}(P_{PID}, P_{PSP}) = I_l\left(l_{TF}, l_{UL}, \frac{w_l}{h_l}, \frac{w_s}{h_l}, d_l, d_w, d_{il}, C_M, C_{CIE}\right) \quad (4)$$

The legibility index is expressed as the performance level reached during of PID elements detection process, which can be measured either as element detection speed or element detection time, $\tau_d(e_i)$ for each PID element.

Another measure of legibility, applicable in particular for text only PIDs is expressed as :

$$I_{legibility}(P_{PID}, P_{PSP}) = \frac{h_l}{d_{pr}^{max}} \quad (5)$$

. where h_l is the letter height and d_{pr}^{max} is the passenger maximum reaction distance. The maximum distance between the passenger and PID for which the passenger can correctly detect the PID elements is the legibility distance. The vision performance level of the passenger affects the element detection speed. Younger passenger legibility distance is greater than older passenger legibility distance.

We define the total time to read as the total time between the moment of passenger arrival at the station point and the end of perception process for all the semantic carriers : letters, words, symbols and icons.

$$\tau_{TTR} = \tau_d(PID) + \sum_{j}^{N} \tau_d(s_j) \quad (6)$$

.where $\tau_d(PID)$ is the PID detection time and $\tau_d(s_j)$ is individual detection time for each semantic carrier. During the cognitive process, the semantic content will be extracted and integrated to contribute to the PID content understanding.

6. Conclusions

The main objective of this research phase was to define the criteria for assessment of the visual representation of PID categories of information, starting from the questioning the visibility, legibility and readability of the display content and their main measurable components. The defined assessment criteria are used to develop a framework for evaluating of existing passenger information displays and improving the performance level of the human-display joint cognitive system. The visibility index, the conspicuity index and the legibility index where defined and analyzed in terms of dependencies. Also the total time to read was defined as a measure of PID effectiveness. The PID evaluation criteria will be used to analyze the performance level of several PIDs used in Bucharest public transport.

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