

Risk Reduction by Evacuation in Transportation System: Pilot Survey with Technology Acceptance Model

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Abstract. Disaster risk reduction is a priority at a global level. For reducing the exposure risk component, mobility and transport system play a relevant role. For these reasons, it is necessary to study mobility under emergency conditions. This paper proposes to increase the knowledge of mobility in evacuation conditions with the support of pilot survey for Technology Acceptance Model (TAM). This approach allows analysts to assess behavioral intentions and provides an effective framework for understanding the acceptance choices of users regarding technology. TAM approach was originally based on two classes of variables commonly defined: perceived usefulness and perceived ease of use. The paper presents the preliminary findings of a pilot survey, conducted during an emergency exercise, following a TAM approach. The hypothesized emergency scenario concerns a laboratory experiment simulating extreme adverse weather conditions and that the municipal emergency plan provides that citizens must reach one of the two safe areas with motorized private modes. The pilot survey collects information that can be used for designing an extended survey in a real context. The framework and obtained results show the possibility to individuate a set of questions related to the TAM approach and their possible aggregation in groups. The findings are useful for analysts and decision makers involved in a risk management process for further analysis.

Keywords: risk · urban evacuation · Technology Acceptance Model (TAM) · pilot survey

1 Introduction

On a global scale, both anthropogenic and natural disasters result in substantial economic losses, which is a matter of great concern. In 2023 Emergency Events Database (EM-DAT) recorded about 400 disasters produced by natural events [1]. For this reason, disaster risk reduction is a priority. At the global level, Agenda 2030 indicates different Sustainable Development Goals (*SDG) related to risk reduction to be achieved by reaching quantitative targets* [2].

This paper focuses on the SDGs and their targets related to disaster risk reduction and the role of mobility and the transport system. In the literature, methods and models are

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proposed to study the mobility of people and goods, with particular reference to ordinary conditions. However, in order to reduce risk, it is necessary to study the evolution of mobility under emergency conditions, in relation to the possibility to activate evacuation procedures from risk areas.

The impact of the evacuation plan can be estimated through the construction and application of transport system simulation models. In this context, it is necessary to integrate models derived from Transport Risk Analysis (TRA) with Transport System Models (TSM) adapted to simulate the exposure component and thus the evacuation procedures [3]. The literature highlights the necessity of reducing the gap between the plans and procedures and the users' capacity to evacuate in a limited temporal interval. The gap can be overcomed through the implementation of discussion-based or operation-based emergency exercises [4]. Exercises may be accompanied by the implementation of surveys combining Revealed Preferences (RP)/Stated Preferences (SP) and Technology Acceptance Model (TAM) questions. In the context of emergency planning, the results obtained through the surveys measure the acceptance and attitude of the users towards the acceptance of the risk, the plan procedures and the information disseminated with Information and Communication Technologies (ICT) [5].

In this context, motivational pilot surveys play a relevant role because they increase the knowledge of mobility phenomena and support the TSM building processes. Pilot surveys are aimed at acquiring information on the travel choices of users in a given transport system configuration. Surveys about travel's choices can be divided into: RP [6]; SP [7]. Recently, classical surveys can be accompanied by the TAM approach to analyse users' behavioural intention and technology acceptance choices [8]. The approach is generally used in the technology sector and recent scientific work proposes the integration of RP, SP and TAM in the mobility sector in ordinary conditions, e.g. to evaluate the implementation of the Mobility as a Service (MaaS) paradigm [9].

This work investigates the possibility of integrating RP, SP and TAM for analysing the mobility phenomena in emergency conditions. To this end, investigations were carried out to assess user behaviour in an emergency scenario involving the activation of an evacuation procedure. The main objective is to design a TAM survey individuating a set of questions and their possible aggregation in classes. The main results of a pilot survey are illustrated.

Following this introduction, the paper is organised into three sections. Section 2 proposes a framework for modelling and investigating user's travel choices in evacuation conditions. Section 3 presents the results of a prototypal application of the proposed framework. Section 4 closes the paper with a discussion and closing remarks.

2 Methods and Proposed Framework

The methods for analysing mobility under emergency conditions include (Sect. 2.1): an integrated set of TRA models for measuring occurrence and vulnerability and for the simulation of transport systems (TSM); a survey framework that integrates RP/SP and TAM approaches (Sect. 2.2).

2.1 Models

According to the literature, risk in transport systems has three components [10]: occurrence; vulnerability; and exposure, which measures the probability that at least one user is present in the area affected by the disaster (individual risk) or the number of users in the area (social risk).

In the context of TRA, one of the main actions concerns the reduction of exposure through evacuation procedures aimed at moving people from areas affected by effects to safe places where the effects are negligible. To this end, it is necessary to plan mobility scenarios under evacuation conditions, assessing the performance of the transport system beforehand. It is necessary to design the system for reducing the exposure component and measuring them through TSM (Fig. 1).

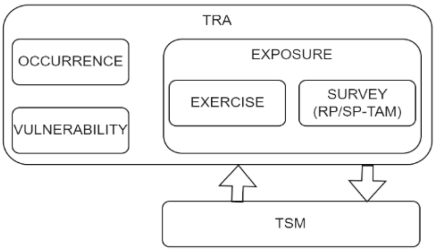


Fig. 1. Methods for analyzing mobility in evacuation condition

Under emergency conditions, the optimal design of the transport system requires the use of TSMs for supporting decision makers and takers during two phases: planning to design the system with different time scales (long, medium, short) with different hypothetical risk scenarios and events; emergency management for operational decisions according to the real risk scenario and in the presence of a real event.

TSMs are commonly used for modelling transport systems under ordinary conditions and can be extended under emergency conditions. They are based on the interaction between two categories of models: demand models and supply models. Demand models are based on modelling user behaviour using non-deterministic utility theory in relation to the congestion on the transport system [11]. Supply models estimate the effects of congestion on systems and thus how performance and impacts are affected by demand flows [12]. The nature of the phenomenon and user behaviour under emergency conditions means that the transport system cannot be simulated under stationary conditions. Therefore, the models to be used range between pseudo-dynamic models for modelling in the context of long-term and medium-term planning and dynamic models for short-term planning activities or real-time controls.

The effectiveness of the evacuation plan depends on its implementation in the context of a real emergency. To this end, it is possible to design and implement emergency exercises with a dual purpose:

1. to increase awareness of the managers and users involved through the presentation of the contents of the plan;

2. to increase the knowledge of the phenomenon on the part of analysts who intend to construct TSM; to this end, it is necessary to design and carry out surveys (Section 2.3) to collect the information necessary for the construction of transport system models under evacuation conditions.

Surveys for acquiring information about user's travel choices can be divided into:

- (RP) Revealed Preferences, aimed at collecting information and quantitative data on users' revealed choices in a real context, in order to estimate their behaviour;
- (SP) Stated Preferences, aimed at reproducing users' choices regarding possible evolutions of the transport system (or scenarios) in order to assess their potential behavior in a hypothetical state of the system.

This paper focuses on the TAM survey. In its original formulation, the TAM approach is based on two variable classes [6, 14]:

- PU, Perceived Usefulness, "The degree to which a person believes that using a particular system would enhance his or her job performance";
- PEOU, Perceived Ease Of Use, "The degree to which a person believes that using a particular system would be free from effort".

It is possible to integrate TAM and Random Utility Models (RUM) approaches for producing more insights into user's travel choices and potential preferences (Fig. 2).

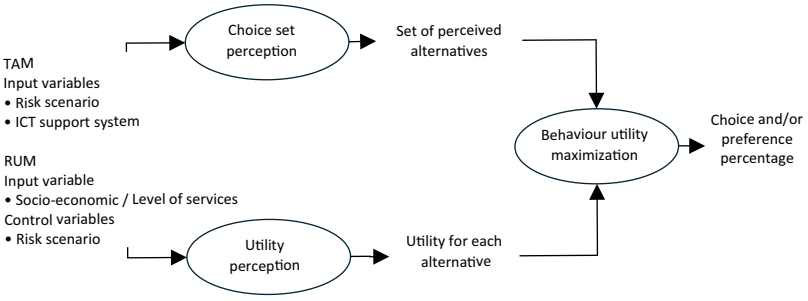


Fig. 2. TAM/RUM logical architecture

2.2 Survey Framework

The implementation of the architecture proposed in Fig. 1 requires a design of a survey linked to the scenarios defined in the evacuation plan to assess the perception of the users. The survey can be part of an emergency exercise in which an emergency scenario is tested. Each scenario illustrates the transport system under different risk conditions, as determined by a disaster event. By taking into account the planned evacuation procedures, the proposed survey framework consists of three steps:

(I) survey and questionnaire design (I. Design);
(II) exercise and survey implementation (II. Implementation);

(III) analysis of collected data, identification of homogeneous groups and feedback for designing (III. Analyses and feedback).

2.2.1 Design

The implementation of the survey can be part of an exercise to be implemented in the manner described in the literature, belonging to the discussion-based class. The exercise consists of presenting an emergency scenario to a sample of users. The spatial context, the emergency event being simulated (e.g. flood, tsunami, fire, …) and the purpose of the exercise are described. At the same time as the exercise is carried out, a questionnaire consisting of two parts is administered to the participants:

- the first part contains RP/SP questions aimed at collecting information about potential travel choices in the emergency scenario;
- the second part contains TAM questions about user's perception of provided information and planned procedure.

By focusing on the TAM part, it is necessary to define unambiguous quantitative variables and qualitative indicators based on an ordinal Likert scale (e.g. 5–7 levels of response). The scale should be structured in such a way as to provide the respondent with a wide range of response choices (e.g. from 'strongly disagree' to 'strongly agree'). The scores obtained and measured on the Likert scale can be analysed both descriptively and statistically.

2.2.2 Implementation

The development of a prototype survey is useful for the design of a more extensive survey. The emergency plan's contents are selected, and their presentation methods are defined. The focus is on the evacuation procedures necessary to reduce exposure. The presentation may be accompanied by the use of multimedia systems, including a simple projector up to a virtual environment to be realized through a serious game [13, 14].

The exercise can be organised in phases in which the evolution of the emergency scenario and the planned actions are presented to a sample. Together with the exercise, questionnaires are submitted to the users. One part of them is characterized by questions belonging to the RP/SP typology. At the conclusion of the exercises, the last part of the questionary contains questions belonging to the TAM typology. If possible, it is important to precede the extended survey phase with a pre-analysis phase using a pilot sample, the subject of this paper.

2.2.3 Analyses and Feedback

After conducting a pilot survey, initial statistical analysis of the individual answers and comparison of the answers between different questions is carried out. The aim is to assess whether the planned procedures are perceived as useful, clear and easy to follow. In addition, a comparison of questions is used to check whether there are homogeneous groups with respect to the answers provided by the sample. The objective is to test a set of questions and to evaluate ex-post the existence of possible aggregations between questions in homogeneous groups. The verification of the presence of groups is done

by specifying a hypothesis statistical test. Several statistical tests are available in the literature, that have to be specified relation to the characteristics of the sample (e.g., independent or non-independent samples), thus on the basis of the initial hypothesis [15]. In this work, a t-student test (t-test) of the averages was adopted, which consists of comparing the averages of the sample's self-reported answers in pairs of questions. The adopted t-test compares the averages of two non-independent samples. The variance of the population from which the samples came is unknown, and the mean of the sample distribution between the means is:

$$\mu_{\overline{x}_1-\overline{x}_2} = \mu_{\overline{x}_1} - \mu_{\overline{x}_2} = \mu_1 - \mu_2 \tag{1}$$

with: $\overline{x}_1$ average sample value 1; $\overline{x}_2$ average sample value 2.

The t-test is specified as follows:

$$t = \frac{\overline{X}_D}{\frac{S_D}{\sqrt{n-1}}} \tag{2}$$

with: $\overline{X}_D$ mean value of the difference in scores between the samples considered, calculated as follows:

$$\overline{X}_D = \frac{\sum(X_{1i} - X_{2i})}{n} = \overline{X}_1 - \overline{X}_2 \tag{3}$$

X_{1i} and X_{2i} observation of user i respectively in the sample 1 and in the sample 2;

S_D Standard Deviation of the samples, calculated as follows:

$$S_D = \sqrt{\left[\frac{\sum D_i^2}{n} - \left(\frac{\sum D_i}{n}\right)^2\right]} \tag{4}$$

n number of observations of the samples

D_i difference in scores, relative to user i, between two samples, calculated as follows:

$$D_i = X_{1i} - X_{2i} \tag{5}$$

The test is the comparison between the average of the two samples: $\overline{X}_1$ and $\overline{X}_2$. The hypothesis formulation is the following:

- The hypothesis of H_0 investigate if there are not differences between the averages of the two samples

$$H_0 : \overline{X}_D = 0 \tag{6}$$

  In this case, the hypothesis H_0 means that the averages of the difference of the scores between the samples considered are equal, therefore:

$$H_0 : \overline{X}_1 = \overline{X}_2 \tag{7}$$

- The hypothesis of H_1 investigates if there are differences between the averages of the two samples, so

$$H_1 : \overline{X}_D \neq 0 \tag{8}$$

In this case, Hypothesis H_1 means that the averages of the difference in scores between the samples considered are different, so:

$$H_1 : \overline{X}_1 \neq \overline{X}_2 \tag{9}$$

The hypothesis of H_0 means that the two samples, with regard to the same question, have the same response behavior; and furthermore, it indicates the possibility of clustering between questions due to the sample's similar perception of the question's meaning. Therefore, in the case of acceptance of the H_0 hypothesis, it is possible to identify a group of homogeneous questions.

Whereas, the hypothesis of H_1 means that the two samples, with regard to the same question, have a different response behavior, and, in addition, indicates the possibility of clustering between questions due to the similar perception of the meaning of the question, in which case the questions compared are not perceived similarly by the sample and thus do not belong to the same group.

3 Results

The method proposed in Sect. 2 was applied in a prototype way. An evacuation plan scenario was assumed to be tested by means of an RP, SP and TAM investigation (Sect. 3.1) carried out and analysed in a real context (Sect. 3.2).

3.1 Models

A tabletop exercise was conducted to experiment with an evacuation plan on a suburban scale. The procedure activation is necessary to deal with adverse weather conditions that could evolve into flooding and inundation.

The designed questionnaire was administered to a limited sample of students at the Università degli Studi Mediterranea in the city of Reggio Calabria in the south of Italy. In April 2024, a prototype was carried out involving a class of university students and some lecturers carrying out activities at the engineering complex in the city of Reggio Calabria. It was assumed that the municipal emergency plan would be activated. The plan establishes that, in the case of the emergency scenario analysed, citizens must reach one of the two safe areas by car:

- to the north, in the territory of Villa San Giovanni, which can be reached either by a route that runs on a motorway (A2 junction) or a route that runs on an extra-urban road, characterized by urban crossings (SS18);
- to the south, in the territory of Motta San Giovanni, which can be reached by a single route on a main suburban road (SS106).

3.2 Pilot Survey

According to the contents of Sect. 2.2, the questionnaire administered comprises two main sections. The first concerns a pilot survey on the RP and SP typologies. The second regards the TAM approach.

3.2.1 Design

The questionnaire section RP/SP is treated in Russo et al. [16] that specifies the RP/SP typology of the pilot survey. Each section is composed of several questions aimed at investigating the users' behavior, in the case of emergency, and in the contexts described above.

This work focuses on the specification and description of the TAM approach. This part of the questionnaire investigates the perceived utility (PU) of the planned procedures, the perceived easy of use (PEOU) of the instructions received during the exercise and the acceptance of the proposed plan (PU/PEOU).

3.2.2 Implementation

The pilot survey introduced in Sect. 3.2 has been built for the real simulated context. Afterwards, the pilot survey has been conducted in a day of March 2024 involving a sample of university students. The sample is characterized by 32 users with a 100% answering rate.

Participants were asked to rate evacuation procedures on a Likert scale against:

(a) compatibility with their mobility habits;
(b) clarity of the plan's procedures;
(c) level of perceived safety;
(d) intentions following the conduct of the exercise, concerning the need to acquire information on available emergency plans
(e) perceived benefits of the plan;
(f) ease of following plan instructions;
(g) clarity of the information provided and contained in the questionnaires.

Each application was associated with 5 levels of answering definite in a Likert scale, structured in such a way as to provide a range of response choices, ranging from "strongly disagree" (1) to "strongly agree" (5).

3.2.3 Analyses and Feedback

The analysis of the sample, thus the descriptive statistics of the simulation, gives information about the main behaviour chosen by users, the latter result to be as follows.

Thereby, the questionnaire has an overall response rate to the TAM questions of 100%. The descriptive statistics of the TAM questions (Fig. 3) in the pilot survey, and in particular the compatibility between the safety instructions and the mobility habits (a) of the analyzed sample was answered with "in agreement" and "strongly agree" for the 78%. As far as concern the clarity of the safety procedures (b) was answered by the sample as "in agreement" and "strongly agree" for the 88%. Moreover, regarding

the clarity the information contained in the evacuation plan (c) (e.g. departure times, modes of transport, routes, areas, …) defined in the plan, the sample answered to be "in agreement" and "strongly agree" for the 84%. Concerning the perceived utility to acquire information on available emergency plans (d) has been answered by the sample as "in agreement" and "strongly agree" for the 75%. In addition, regarding to the perceived benefits of the evacuation plan (e) has resulted "in agreement" and "strongly agree" for the 63%. The examined sample found the easy to follow the plan instructions (f) with "in agreement" and "strongly agree" for the 56%. Lastly, concerning the clarity of the information provided and proposed in the questionnaires (g) the sample was "in agreement" and "strongly agree" for the 59%.

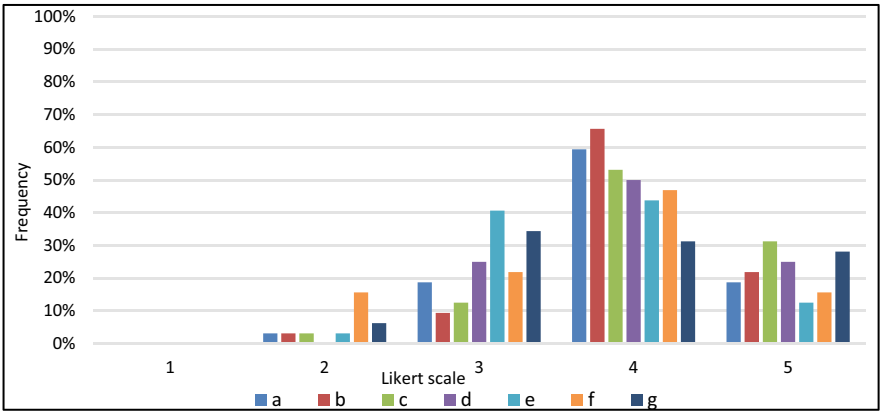


Fig. 3. Statistical analysis of the sample surveyed

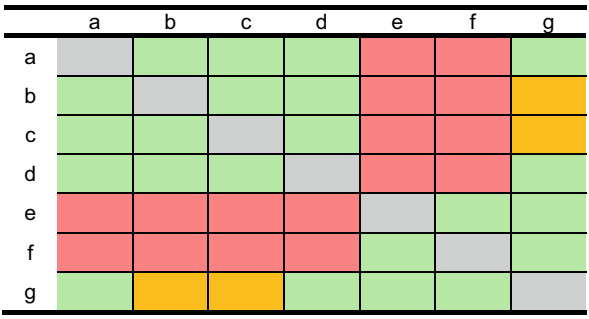
As far as concerns the inferential statistics analysis, thus t-student test, specified in the Sect. 2.2 (Eq. 2), the answers have been analyzed for individuating possible groups of answers.

The t-student test has been carried out with the following specifications:

- Number of observations: 32
- Degree of freedom: 31
- Critical value (95% of significance, 31 degrees of freedom), $t_{0,95,31}$: ± 1.696

4 Discussion

The results reported in the Fig. 4 with the acceptance of the test clearly underline the similarity between questions which indicates the possibility to cluster them. Therefore, the t-student test indicates a similarity between the questions (a), (b), (c) and (d); moreover, it is individuated a cluster among the questions (e) and (f), however there is a long distance between the first and the second described clusters, thus a very low similarity. The question (g) results to stands alone in the cluster, due to the fact that summarizes all the work carried out in the survey. Additionally, the results show the low distance to the first and second clusters, thus low similarity.



green=test accepted; orange=test accepted (almost rejected); red=test rejected; grey=empty

Fig. 4. Results of the t-student test inferential analysis.

The result is explained by a possible construction of the questions in a similar structure, characterized by an almost equal objective and therefore in addition by the similar perception among the questions by the analysed sample.

The results obtained from the analysis of the independent sample, thus the pilot survey show the attitudes of the respondents towards an evacuation procedure in an emergency plan. Compared to a classic motivational survey, the TAM survey provides more information about the level of acceptance of plan procedures.

The first result concerns the analysis of the descriptive statistics of the responses declared by the users. Figure 3 shows that in all questions submitted, the highest frequency is recorded at level 4, as well as by considering the investigated questions 4 and 5 the main rate of the total answers is observed; consequently, the sample results to be predominantly in agreement and strong agreement, thus with the goal of the questions.

The hypothesis tests also shows the presence of similar user attitudes with respect to question aggregation (groups), hence the latter result to be an important result in terms of questions interpretation, hence gives important information about the possible future research directions and lack bridging. The analysis of Fig. 4 shows the presence of three groups. Group 1 consists of questions (a), (b), (c) and (d). In fact, the comparison of the averages between the pairs of questions shows a similar attitude of the users. Group 2 consists of questions (e) and (f). The t-test performed between the two questions shows a discordant attitude. Lastly, group 3 comprehend question (g), it results to be a summarizing question.

5 Final Remarks, Limits and Perspectives

Disaster risk reduction is a priority goal defined at the global level. One of the main actions for achieving this goal regards preparedness to the community. This paper focused on the exposure risk component that can be reduced designing and implementing an evacuation planning process. However, it is necessary to reduce the gaps between planning definition and its implementation in a real emergency situation. This paper proposed to design and implement a pilot survey based on a TAM approach. The final aim is to measure, from one side, risk's perception of the end-users that must be moved from a

dangerous to a safe area by following the planned evacuation procedures; from another side, adopting the TAM approach, it is possible to measure the Perceived Ease of Use of information that planners provide to the end users in an evacuation procedure. The first prototypal pilot survey shows promising results of implementing the proposed approach.

This paper presents some limitations. The main limit of the obtained results regards the representativity of the sample. It is underlined that the performed pilot survey has involved a reduced number of people. This is due to the necessity to produce a pilot survey, in order to verify the achievability of the specified methodology, thus to address a more complex and extensive investigation. The objective is to understand the users behavior in relation to the exercise, which has been performed in a simplified way, hence considering that the context was not real but simulated by means of providing indication about the plan. Therefore, to fill the latter limitation it would be possible to upgrade the exercise context. The answers given by users are related to the fact that the context was given simplified. Moreover, there is not a link with RUM, because it is a descriptive and not a behavioral analysis.

In the future, this research can be extended in different directions. In future stages, it is possible to extend the dimension of the sample and submit the questionnaire, with the same hypothesis, to a further sample and analyze the answering behavior with the model specification proposed in the paper, as an independent sample. Therefore, it is possible to compare both samples, and extend the analysis in terms of dependent sample, thus considering the correspondent users of both samples. Consequently, after the latter preliminary considerations, it is possible to identify as a first research's direction regards the formulation of evacuation planned scenarios near to real phenomena connected to disaster. The second direction concerns the possibility of using the obtained results for increasing knowledge about user's behavior in evacuation conditions. This is possible by integrating TAM with Random Utility Models (RUM) adopted inside the Transport System Models and/or Bayesian Networks. The last research direction should produce more insights into the potential integration between TAM pilot surveys and emerging ICT tools. The support of digitalization and automation processes for performing pilot surveys.

This work is useful for the transport planners and decision-makers for the reduction of the exposure risk component by means of solutions concerning mobility and transport systems in evacuation conditions. Moreover, it is investigated the impact of TAM in the latter context.

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