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The Risky-Opportunity Analysis Method (ROAM) to Support Risk-Based Decisions in a Case-Study of Critical Infrastructure Digitization

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Abstract: Socio-ecologic, socio-economic, and socio-technical transitions are opportunities that require fundamental changes in the system. These will encounter matters associated with security, service adoption by end-users, infrastructure and availability. The purpose of this study is to examine and overcome the risks to take advantage of opportunities through the novel Risky-Opportunity Analysis Method (ROAM). A novel quantitative method is designed to determine when, after making some changes, the risks become acceptable so that the opportunity does not deviate from the objectives. The approach provided a quantitative evaluation of the possible changes in parallel with digitization, towards providing a green Service Supply Chain (SSC). The result of ROAM shows that the most cost-effective change to increase the resilience of the system is a solution (SMS) which is different from that identified by a TOPSIS multi-criteria method. Real-word decisions in change management should tackle the complexity of systems and uncertainty of events during and after transition through a careful analysis of the alternatives. A case-study was carried out to evaluate the alternatives of an ancillary service in the Payment Service Providers (PSP). The comparison of the ROAM results with the traditional TOPSIS of the case-study unveils the priority of the ROAM in practice when the alternatives are Risky-Opportunities. The existing risk assessment tools do not take advantage of risky opportunities. To this aim, the current article introduces the term Risky-Opportunity, and two indexes—Stress and Strain—of the alternatives that are designed to be employed in the new quantitative ROAM approach.

Keywords: risky-opportunity analysis method (ROAM); socio-ecological transition; cyber–physical–social systems; change management; risk management; critical infrastructure resilience; digitization; risky-opportunity (RO); payment service providers (PSP)

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1. Introduction

Innovation and change are the foundations of sustainable development and contribute to creating a resilient future. To this aim, it is crucial to consider a risk-based approach to carry out transformation in real-world complex systems (Holton 2020; Waddock et al. 2015). The scope of this study is Critical Infrastructures (CI) and their role in the transformation of complex systems. Digitization of CI is a hot trend that bonds society with technology (Holton 2020; Pidgeon 2020; Stasik and Jemielniak 2021) leads to the transformation of complex systems into cyber–physical–social Systems (CPSS). However, as CIs provide a vital service to society, their transformation needs responsible involvement (Glerup and Horst 2014): the changes should not interfere with service continuity of CIs, but new ways of delivering services should be accepted by society (Gravesteijn and Wilderom 2018). Payment Service Providers (PSP) are CPSS that can be considered both as a critical entity of society and pioneers of digitization. However, such transformation is a risky process, and the complexity of CPSS escalates the uncertainty and risks respectively (Pidgeon 2014; Schweizer 2019).

Digitization is a sustainable solution for the future that aims to exploit opportunities behind the automation of the system, but it needs some changes in the main service or its ancillary services; these changes are associated with risks concurrently (van der A and Sijm 2021). There is a gap in transformation studies of critical and complex service systems. Extensive research has been focused on risks in the production sector, while far fewer studies have investigated the transition to risk-free services (Asenova et al. 2011). Socio-ecological, socio-economic, and socio-technical transformation (Bechtold et al. 2017; Hietala and Geysmans 2020; Jean-Jules and Vicente 2020) is essential to produce a systematic change towards the concept of sustainable service. This was the main motive of carrying out the case study on a critical entity.

E-Payment has been considered a traditional complimentary service in financial systems, which is provided by PSP companies. This service creates hazardous waste in the service supply chain of PSP companies through payment receipts. Thermal papers, which are widely used in the e-Payment service as receipts, are indeed toxic (Ehrlich et al. 2014) because they contain non-negligible quantities of reactant acid (usually bisphenol A—BPA) (Braun et al. 2009; Ullah et al. 2018; Vandenberg et al. 2007; Zhou et al. 2019). Thermal paper is not only a cause of health issues, but it must also be recycled separately from other papers. Therefore, a change in the way this service is provided is necessary for PSP companies to move towards green service.

The paper is the result of a research project aiming at devising an approach to support decisions, taking into consideration the concept of Risky-Opportunities. The novel quantitative method determines when, after making some changes, the risks become acceptable, so that the opportunity does not deviate from the objectives. With this aim, the ROAM approach is proposed with the help of a case study in which a multi-dimensional analysis employing ROAM is carried out in order to find the most effective way for a transition towards sustainable service in PSP companies.

Indeed, different solutions to eliminate, reduce, or manage the waste in the life cycle of thermal papers are possible. Nevertheless, different methods provide different ecological and economic benefits, but they are also associated with some risks and resource requirements to enable the change in the company's activity and processes. Resource allocation is crucial when the available resources are limited (Chen and Dong 2018). The Risky-Opportunity Analysis Method (ROAM), based on an Analytic Network Process model, compares the resource consumption and assesses risks for substituting the existing receipting system with an eco-friendly one. The outcome of this method is the most feasible way of introducing a change in the PSP for its transition towards sustainability.

1.1. Resilient and Sustainability of PSP Service Supply Chain

The electronic payment service is a developed digitalized sector of e-commerce that enact online payment methods (Andersen et al. 2004; Eduardsen 2018; Goel and Venkat Narayana Rao 2019). Notwithstanding, the security and reliability risks are evident in e-commerce (Salama et al. 2011; ur Rehman et al. 2012); yet, this service provider aims to facilitate e-payment through providing digital transactions methods instead of cash payment. Due to the nature of this service, the payment service provider (PSP) employs outsourced suppliers for a part of the required ancillary service such as telecommunication service providers, internet service providers (Choi et al. 2006; Ma 2013).

PSP performs other activities such as providing POS terminals for intermediary role players such as shop owners and documenting the transactions by printing a receipt at the payment point. In a nutshell, the payment service providers along with third parties, end-users, and intermediary role players inaugurate a network of cyber–physical–social system within the e-payment supply chain.

The final users of this service are the whole nation in the country; therefore, this sector is vital for society and needs a social engagement too (El Bassiouny et al. 2018; Gravesteijn and Wilderom 2018). This means that the PSP is a critical entity and the study of resilient and sustainable functioning of this System of Systems is crucial. In this article, we adopt a process perspective (Azapagic 2003, 2010). Since PSP is a service-based business (Pallaro et al. 2017), the aim is to devise a more sustainable process by specifically focusing on an ancillary service of the system, which is providing payment receipts. This service can be investigated as an instance of a supply chain.

The investigation of the resilience of a service supply chain has started in 2002, and has been focused on redundancy and reserving a part of the available resources of the enterprise to be utilized after a disruption (Sheffi and Rice 2005). Indeed, most of the studies about the resilience of the supply chain have explored disruption risks (Blos et al. 2010; Ji and Zhu 2008), logistics (Karimi 2009; Wang and Ip 2009), banking projects risks (Khalilzadeh et al. 2020), cash management risks (Michalski et al. 2017) and security (Engelhard and Böhm 2013; Weber 2010) until 2014, when (Winston 2014) raised the issue of resilience and climate change. After that, the resilience of service providers and the environmental pillar of sustainable development have been common research topics (Paterson et al. 2014).

Even if many studies have had the core services as investigation targets, some have been focused on ancillary services. For instance, in 2017 a case study of a cement factory focused on ancillary services of the cement producer and studied the service resilience with environmental aspects and considered green supply chain as a factor of resilience in competitive international markets (Jamali et al. 2017). In all of the above-mentioned studies, emission and climate change were key points of resilience and sustainability of the service supply chain. The present paper investigates the opportunity to make a service supply chain (i.e., PSP) more resilient (Arva et al. 2020) by changing the way in which one ancillary service (printing the receipt using thermal paper, a toxic solid waste (Akilarasan et al. 2018)) is presently performed. This transition must consider the risks of substituting the old ancillary service with a resilient one, the possibility to improve the risk-taking capability of the supply chain, and the resources required to make the transition. In the next subsection, the research on risk assessment and resource consumption in risky transitions will be summarized.

1.2. Risk and Resource Consumption Evolution in the Literature

In the introduction, risky-opportunities were defined and a new method was suggested as a solution that offers a different view on opportunity management and resource allocation. A survey of the literature has been conducted and the results prove the importance of carrying out an investigation on risky opportunities and resource allocation, as studies on these are currently lacking.

Hetrick (1969) stressed the need for a screening definition of an opportunity; he used the Monte Carlo method and the balancing of risk on different projects. Some studies emphasize the need to use the positive effects of uncertainty, and there are case studies that focused on opportunity management besides the risks (Peker et al. 2016; Saaty 2015; Wiratanaya et al. 2015). In particular, Hillson (2003), Ivascu and Cioca (2014) and Olsson (2007) investigated the kinds of opportunities associated with different levels of threats that could provide an advantage to companies or projects.

'Risk-taking' is not a new concept. Research on risk-taking started in 1944 in a study on proportional income taxation (Domar and Musgrave 1944), then in 1965 on individual risk-taking (Lefcourt 1965), and in 1970 group risk-taking was studied by other researchers (Teger et al. 1970). At the personal level, one who believes he is competent in making decisions tends to see more opportunities in future uncertainty than threats (Krueger and Dickson 1994). However, at the management level, it is necessary to consider both sides; so an effective project manager needs to effectively manage risks while taking into account both threats and opportunities (Steed 2000), and, in general, the management of uncertainty for projects should include risk management and opportunity management (Ward and Chapman 2008).

At the project level, the objectives should be protected from any deviation caused by the negative effects of future risk. This mitigation will be the result of specific measures implemented in advance. Therefore, some resources should be assigned to put the measures in place. In light of the existing literature, resource allocation is of paramount importance for risk acceptance. From a decision-making viewpoint, resource allocation is a very important step of a structured decision-making process.

The first research on resource allocation decisions in risky environments was conducted at Victoria Hospital in 1975 and published in 1979 (Kirudja 1978). Nowadays, resource allocation analysis is more popular and it is discussed in studies on uncertainty and risk management, such as in risk-based surveillance (Alban et al. 2020), resilience-based studies (Lenjani et al. 2020), safety (Vamvakas et al. 2019), healthcare (Grant et al. 2019) and others. The two most-cited articles which consider resource consumption in risky environments are in the cloud-computing subject area (Buyya et al. 2008, 2009). All these papers confirm the significance of resource consumption planning in risk management.

From a risk management methodological point of view, one of the most important methods supporting the analysis of opportunities and threats, is the Benefits, Opportunities, Costs, and Risks (BOCR) approach (Saaty 2001). Projects are evaluated from all aspects: risks, opportunities, costs, and benefits, by means of the Analytic Network Process (ANP) to select the best project or portfolio (Mohammadi et al. 2015; Tchangani 2015; Wijnmalen 2007). This approach is criticized by some scholars. For instance, the ratio $\frac{B}{C \cdot R}$ is criticized because some researchers believe that 'the product of costs and risks is not meaningful' (Millet and Wedley 2002) or 'opportunity and risk priorities could be regarded as probabilities' (Wijnmalen 2007). However, in practice, pairwise comparisons are done with respect to importance, preference or likelihood, so the priority vectors derived from them are for Importance, Preference, or Likelihood. The concept of 'likelihood' is very similar to that of 'probability'. Wijnmalen's point was that opportunity and risk refer both to the future, and we are on much shakier ground when making judgments and deriving priorities there.

Resource allocation can be performed effectively if it is supported by a quantitative evaluation. Several Multi-Criteria Decision-Making (MCDM) tools have been employed to this end (Li et al. 2016; Saaty 2008; Saaty and Peniwati 2013; Tulasi and Rao 2015). The method proposed here is also based on MCDM concepts and can be used to evaluate the risk-taking capability of a company, with the aim of accepting a certain level of risk to seize an opportunity, and, at the same time, specify the quantity of resources needed to seize the RO at the project level. ROAM is a quantitative approach that aims to select the most efficient way to accept a RO. To this end, this method provides the Stress–Strain curve to compare the results of carrying out different alternatives, as it will be detailed in the case study in Section 3. In summary, the method is founded on comparing the acquired risk-tolerance of the company after the implementation of each alternative: this is a key difference between ROAM and other decision-making methods, which provide intervals for risk tolerance or are based on certain positive and negative distances from the decision maker's preferred conditions.

The main contribution of this study is a decision support system for complex decisions of critical infrastructures socio-economic, socio-ecologic, and socio-technical transition decisions to choose the best efficient risky-opportunities with the most reasonable resource consumption. The structure of the article is as follows. In Section 2, the methodology of the research and the material that is used are listed. In Section 3, a detailed description of the implementation of ROAM method is presented. In Section 4, the results of the analysis are illustrated and discussed. Section 5 includes the highlights of the ROAM method implementation in other cases. Section 6 provides the limitations and future research recommendations. Finally, the conclusion is presented in Section 7.

2. Materials and Methods

2.1. Materials and Supporting Software Tools

Aghazadeh Ardebili (2020) and Aghazadeh Ardebili et al. (2019, 2020) investigated the service supply chain of a PSP company. In those papers, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was used to prioritize the alternative solutions; in the current study, the same alternatives will be assessed through the ROAM approach; the final results will be compared with the results obtained from the traditional analysis of the alternatives that do not consider the ROs and risk acceptance.

In this research project, data were collected through interviews and literature review. There were three main criteria to select the interviewees: their willingness to share ideas and experience, an actual experience of work in the PSP sector and openness. An unstructured interview was performed in the form of an in-depth interview according to the method described by Ritchie et al. (2003) to collect general information about the critical service (the payment service is critical for society and it is provided by Banking Critical Infrastructure role players). In addition, a literature review was performed to identify the alternatives to using thermal paper and hard-copy of receipt, and an appropriate MCDM method to evaluate the alternatives. The literature review showed that employing ANP is one of the most efficient methods to consider different factors in decision making under uncertainty and with mutual interactions (Bouzarour-Amokrane et al. 2012). The ANP enables the decision maker to include benefits, opportunities, costs, and risks (Saaty 2016; Tchangani and Pérès 2010), in addition to competence, experts, criteria, preferences and alternative solutions (Becker et al. 2017). The previous step was followed by a semi-structured interview that was carried out to collect data about PSP companies. A total of 12 experts from three categories were interviewed (Switch developers, traditional POS developers, and Android POS developers). It was therefore possible to identify and evaluate the alternatives to thermal paper, considering the ROs and quantifying the evaluation criteria. On the other hand, 600 end-users of the service were interviewed through a list of pre-defined questions. The results were used to build a TOPSIS model. Aghazadeh Ardebili (2020) detailed the data collection of this phase.

The last step in the project was to employ ROAM and then compare the results with TOPSIS. Another set of interviews was performed in this phase. The purpose of these was to explore the possibilities of software development to eliminate the paper receipts considering risks and opportunities; therefore, two engineers with computer science background (software engineer and a hardware engineer), and two process engineers (R&D expert and Data analyst) were added to the group of experts for the interview. In this phase, the data for the comparison matrix were collected through semi-structured interviews. The 9-point Saaty Scale is used for pairwise analysis. Some additional questions were asked to clarify specific points during the interview.

The decision support tool *Super Decisions V3.2* was used for the Analytic Network Process analysis. Some of the figures and tables in Section 3 were produced by means of this software. The tool can be used to implement Analytic Hierarchy Process (AHP) and ANP models for combining judgment and data to effectively rank options and predict outcomes. To have a common definition of the terms in the remaining of this article, Table 1 define the key terminology.

2.2. Outline of the Steps

Risk management is a process that typically includes 4 main steps that are updated as a cycle during the project life-cycle (Conroy and Soltan 1998). However, many practitioners prefer to customize the general 4-Step Risk Management Plan with further detailed steps (Burnaby and Hass 2009; Mazareanu 2011; Ward and Chapman 2008).

Figure 1 is an illustration of the cutting edge logical flow of the new method within the general 4 step model of risk management.

Table 1. Terminology and definitions.

No	Term	Definition
1	Risky-Opportunity (RO)	First of all, it should be reaffirmed that some of the terms used here, such as 'project', 'risk manag-ement, and 'risk management plan', are accepted definitions in the literature. However, 'risky-opportunity' (RO), which is used in this paper, does not mean an uncertain event with pure threats or an uncertain event with pure opportunities. ROs are future uncertain events that can have both positive and negative effects on the project objectives at the same time.
2	Main and Secondary Goals	In project management, the word 'outcome' signifies the results of a work package. The final outcomes are the deliverables of the project. Objectives and requirements are necessary to assess the quality of an outcome. For example, the outcome of the digitalization project is a service that passed all the service quality requirements and it is ready for functioning. The term 'goal' in this study is used in two ways. There are two kinds of goals for a new risk management plan. The main goal is to achieve the best outcomes for the project. All of the activities are planned and undertaken for this reason. In general, a risk management plan is followed to control future uncertain events so there will not be any deviation from the main goals. The secondary goals include achieving the objectives of the decision-maker (DM) even if it means going ahead with a RO and accepting the risks it may bring to the main project. This group of objectives should parallel the main project objectives. In short, it includes the objectives of a new decision, which was not originally a part of the main project but must be made for seizing some opportunities.
3	Risk Response	Risk response is the strategy whereby decision-makers plan how to deal with each risk they can foresee. The four kinds of response to risk are: avoid, mitigate, transfer, accept.
4	Pure Threats	The term Pure Threats of an RO stands for the disadvantages of the RO,which could cause possible deviations from the objectives associated with each alternative way of accepting the RO.
5	Pure Opportunities	'Pure Opportunities' of an RO are the certain benefits that might be gained by accepting the RO regardless of the threats. The obtainment of such benefits is not affected by the threats of the RO. e.g., hiring a new contractor, the main goal in this method is taking advantage of RO by achieving these opportunities.
6	Alternative	The alternatives are the different actions that can be taken in order to accept the risk. Taking measures according to an alternative, the risk tolerance of the firm should be improved. For each alternative, the weights of an RO are calculated by means of ANP.
8	Stress	We use the term 'Stress' in a novel way in this study. The major difference between this term and the usual similar terms, such as risk, threat and hazard are that Stress quantitatively includes likely threats, costs, opportunities, and benefits of an event, which is going to be implemented in the new method based on risk acceptance. Thus, Stress is a novel index to show the relative importance of opportunities and benefits, of an alternative to the threats and costs of it to be able to accept an RO. Mathematically, Stress is the ratio of the weights of all threats times costs to the weights of the opportunities times benefits of an alternative. These weights are calculated by ANP in step 5 of the process (Figure 1). The Stress value changes if any changes affect the weights of the threats, costs, opportunities, or benefits: their weights indeed depend on the elements of each cluster during the project life-cycle. This makes the index dynamic as it is a parameter dependent on variables, it is different from the traditional static concept of risk. The Stress value will also change if the amount of resources required for the alternatives varies due to changes in the variables.
9	Resources	Any project will have an initial specific amount of resources to get work done successfully including people, capital, knowledge, and/or material goods. In this method, resources are the part of the resources for the whole project that can be employed to make the changes; that is, they can be allocated to the new alternatives in order to take advantage of the ROs. They may include human resources, budget shifts, assets, material resources including consumables, and time.
10	Basic consumption	Each alternative way to seize ROs implies performing new actions that consume a specific amount of resources. Basic consumption stands for the cheapest alternative; in other words, basic consumption is the sum of all of the resources needed to take the new actions which constitute the alternative with the lowest cost. The cheapest alternative will be used to calculate Strain of all the alternatives.
11	Strain	Strain is the ratio of the amount of resource consumption to basic consumption (see Equation (8)). A numerical example of Strain calculation for different alternatives is presented in Section 3.

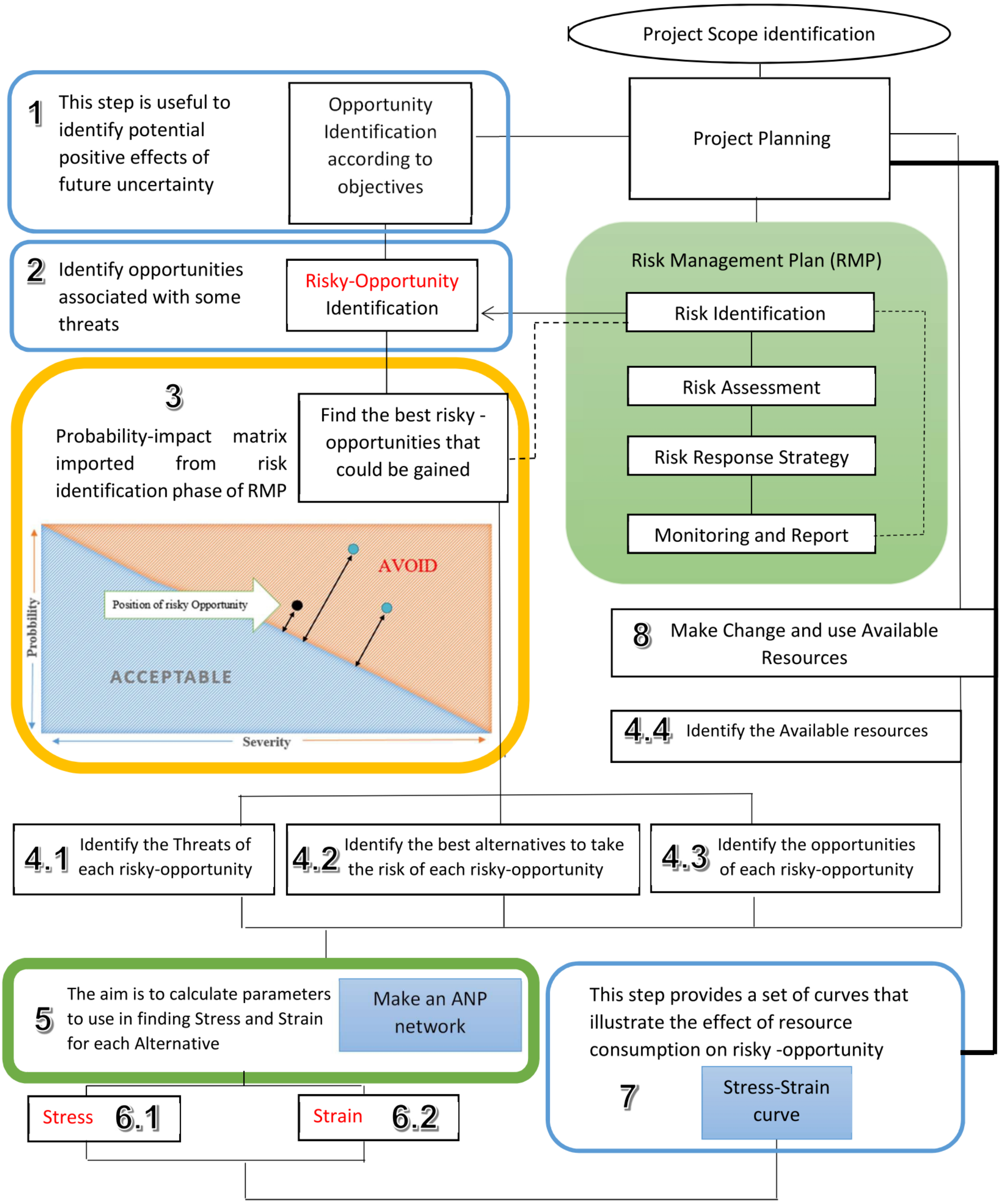


Figure 1. General process of the digitalization risk acceptance evaluation employing ROAM (Aghazadeh Ardebili 2020).

This flowchart divides the action plan of complex processes into manageable steps. The project starts with identifying the scope and project planning: the classic risk management model is shown inside the green box. RO analysis method begins after the first step of the risk management plan—risk identification. Defining risky-opportunities takes the opportunities into consideration according to the project scope and objectives. As previously discussed, uncertain events associated with threats may include some opportunities and some positive effects. Then, different alternative ways to address the threats and seize the opportunities of ROs can be devised. Other RM methods do not consider changes, and uncertain opportunity remains unavailable.

In the following the outline of the steps of the evaluation procedure proposed in this paper is presented.

1. Implementation of the RO analysis method (ROAM) at the project level starts after defining the work breakdown structure (WBS) of the project. The first step is the definition of the main project objectives and scope, followed by clarifying the project sub-objectives, requirements, and required resources. In the case-study discussed here, the main project is digitalization of the PSP service supply chain and the sub-project is the transformation of the transaction report production into an eco-friendly method.
2. The next step is to identify alternative solutions to the traditional thermal paper receipt.
3. It is crucial to choose the feasible and most effective alternatives to continue the analysis. The following criteria will be employed to select the most advantageous alternatives:
    - Economic criterion,
    - Importance of achievement,
    - Feasibility,
    - Congruence.
4. In this step the threats associated with the selected alternatives, which are defined as ROs, are identified. The output of this step is a probability-impact scheme for the threats and impacts of each RO.
5. This step includes five sub-actions to calculate the required parameters through the ANP; the results are then employed in the next step in order to calculate Stress and Strain of the Alternatives.
    (a) Identify the decision criteria for ANP.
    (b) Clustering.
    (c) Identify relations between clusters, and between the elements of the clusters.
    (d) Construct the network.
    (e) Pairwise comparison matrices(PCMs) and solve the ANP Saaty (2004, 2005). In this paper Super Decision 3.2 was employed to calculate the overall priorities for the threat. The procedure of ANP can be summarized as follows (Barzilai 1997; Piantanakulchai 2005; Saaty and Vargas 2006):
        - Construct a pairwise matrix through quantifying the preference of the DM using 9 scale ranking (Barzilai 1997). If n objects should be compared, the number of comparisons is $\frac{n(n-1)}{2}$
        - If i represent the row number and j represents the column number of the matrix, the lower diagonal should be equal to ($a_{ij} > 0$):

$$a_{ji} = \frac{1}{a_{ij}} \tag{1}$$

It is crucial to have consistent judgements considering the whole comparisons in the above mentioned matrix (Alonso and Lamata 2006). Therefore, it is fundamental to check the Consistency Index (CI) of the matrix. The basic Consistency Ratio (CR) control is introduced by (Saaty 1980) using the following procedure:

$$\lambda_{max} = \Sigma(EigenVector) \cdot \Sigma\left(Column_j\, of\, reciprocal\, matrix\right) \tag{2}$$

λ_{max} is the largest eigenvalue.

$$CI = \frac{\lambda_{max} - k}{k - 1} \tag{3}$$

In Equation (3), k is the eigenvalue of a perfectly consistent matrix. In this stage, the RI (Random Consistency Index) is extracted from Table 2 and the CR is calculated (Equation (4)). The values of RI were obtained from 10,000 randomly generated PCMs (Thurstone 1927). Therefore the value of RI depends on the matrix order

Table 2. Random consistency index.

Order	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

$$CR = \frac{CI}{RI} \tag{4}$$

- Measure the consistency from Equation (4) (Koczkodaj 1993; Saaty and Vargas 2006).
- Construct the Unweighted Supermatrix Figure 2 of the network and then multiply the weights. In this study, the Super Decisions software was used to calculate the weights of the ANP method; therefore, all the calculations were performed by the software. Super Decisions follows the approach detailed by Saaty (2016).

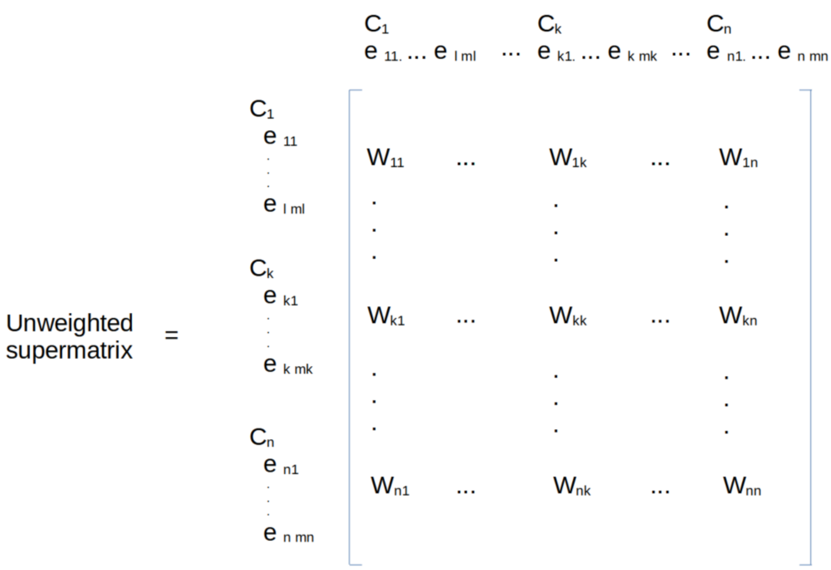


Figure 2. Unweighted Supermatrix. C is the cluster when $k = (1 - n)$ and W_{ij} is the priority vector extracted from pairwise matrix.

- Raising the Weighted Supermatrix to the limiting power (l) the global priority vectors are obtained.

$$\lim_{k \to \infty} w^l \tag{5}$$

In case of cyclicity effect, the Equation (6) is used

$$\lim_{k \to \infty} \left(\frac{1}{n}\right) \sum_{i=1}^{w} W_i^k \tag{6}$$

6. This step includes two sub-actions.
   (a) Stress is calculated as follows:

$$Stress_{alternative} = \frac{\sum \mathrm{TW} \cdot \mathrm{CW}}{\sum \mathrm{OW} \cdot \mathrm{AW}} \tag{7}$$

   where:
   OW, the benefit subnetwork will calculate the weight of all of the pure opportunities for each alternative. To calculate the denominator of the stress of each alternative (A_i), the pure opportunities associated with that alternative will sum up and multiply to the alternative weight.
   AW, the opportunity subnetwork will calculate the weight of alternative-i (A_i) related to RO_j according to the objectives.
   TW, the risk subnetwork will calculate the weight of all of the pure threats for each alternative. To calculate the numerator of stress for each alternative (A_i), the pure threats associated with that alternative will sum up and multiply to the cost weight.
   CW, the cost subnetwork will calculate the weight of alternative-i (A_i) related to RO_j according to resource consumption.
   (b) Strain is calculated as follows:

$$Strain_{alternative} = \frac{\sum \mathrm{ARR}}{\mathrm{BC}} \tag{8}$$

   where:
   ARR, Available Required Resources to perform the activities of an alternative
   BC, Basic Consumption, i.e., the resources needed by the cheapest alternative
7. In the last assessment step, Stress and Strain of each alternative are used to find the position of the A_i in the Stress–Strain coordination system. Each alternative has a specific point in the space.
8. After the assessment, a sub-project will be introduced in the form of an operation plan in order to meet the selected alternative work-package. The RO which is accepted through the ROAM is a way to change the original firm/project aims to exploit the benefits of such RO. The resources that are needed for taking the measures are already foreseen during the Strain calculation for the RO. Therefore, the project will be carried out consuming the estimated resources.

The process of evaluating the risks will be performed continuously during the entire life-cycle of the main project to identify new ROs.

3. Outline of the Steps of the ROAM in the Case-Study

In this section, ROs analysis of the PSP company employing ROAM will be explained systematically. The procedure of calculations is explained in the previous section.

3.1. Goal of the Project

The main goal of this project is to analyze the ROs related to the socio-economic and socio-ecologic transition of a PSP company towards a green supply chain. A recent study on the PSP supply chain (Aghazadeh Ardebili et al. 2020) showed that the elimination of thermal paper from the supply chain ancillary service could bring about environmental, social and economic opportunities. Specifically, the following opportunities can be mentioned: eliminating the production of toxic waste during the service supply chain, reducing the traffic caused by maintenance shuttles of the POS devices, reducing the burden of maintenance activities through digitization of the system (Plesner and Raviola 2016; Plesner et al. 2018), and finally eliminating the delivery of the thermal paper to the end-users of PSP service to avoid its dangerous consequences on social health.

3.2. Identification of the Alternatives

In the previous studies (Aghazadeh Ardebili et al. 2019, 2020), two kinds of alternatives were identified in this supply chain. Using e-Receipt to eliminate thermal paper receipt production, and using a combination of e-Receipt and paper to reduce thermal paper production. Both alternatives are associated with some threats; therefore, they can be considered as key ROs in this analysis.

3.3. Feasible Alternatives

The above citepd studies showed that three of the ROs are not feasible because of the cost, or high impact and probability of threat occurrence. Table 3 displays the probability and impact of the threats for each alternative. Alternatives 5,8,9 were already removed from the analysis; for the next steps of the analysis six alternatives will be considered:

RO1 includes the e-Receipt methods:
A1. SMS;
A2. Email;
A3. Application notification;
RO2 includes the combination of e-Receipt and paper in case of transaction failure;
A1. SMS or Print;
A2. Email or Print;
A3. Application notification or Print.

3.4. Probability-Impact

The assessment of Probability-Impact of the issues related to the alternatives is necessary to support pairwise comparison. In Table 3, all of the issues, including the Threats (T), Opportunities (Op), Benefits (Be), Costs (Co) of the ROs, and their alternatives are listed. Regarding the identified costs, HRM, assets of the company (servers), and budget in cash are the resources that this company needs to implement these alternatives. As can be seen in Table 3, there is no opportunity or benefit that is not likely or has a negligible impact on improving the service if the sustainability pillars are considered. In addition, there is no threat or cost that is highly likely and has an extreme impact on making problem in the service. Therefore, we will not eliminate any alternative.

3.5. Parameters Calculation

This step includes different sub-steps to construct the network and solve them by the ANP.

3.5.1. Decision Criteria

The decision criteria in the current analysis are chosen according to all three sustainability pillars, because the main goal of accepting RO aims at transforming the supply chain ecologically, economically, and socially towards a green supply chain. However, the key to this transition is the digitalization process (Jedynak et al. 2021; Liu et al. 2021); therefore, the technological aspect is also included among the criteria in this analysis.

3.5.2. Clustering

The elements in each cluster are listed in a separate table, similar to the example of the threats in Table 3 (the tables for opportunity, cost, and benefit are available in the Appendix A). The table illustrates how each element is a factor pertaining to specific decision criteria.

Table 3. 'Pure Threat' cluster elements: a * shows that the factor Ti pertains to the criterion on top.

No.	Threat Description		Criteria			
	Issue	Threat	Soc.	Econ.	Env.	Tec.
T1	Security	Information accuracy	*			*
T2		Cyber security	*			*
T3	Service adoption	Purchaser	*			
T4		Vendor	*			
T5	Availability	Purchaser				*
T6		Vendor		*		*
T7	Environment	Unnecessary shuttles	*		*	
T8		Thermal paper usage	*	*	*	*
T9	Service providing issues	Data transfer speed				*
T10		Trouble shooting speed				*
T11	Infrastructure	Internet network (national)	*	*		*
T12		Internet connection		*		*
T13		Telecommunication network issues				*
T14		Network data issues				*
T15		Mobile internet issues	*			*

3.5.3. Relations

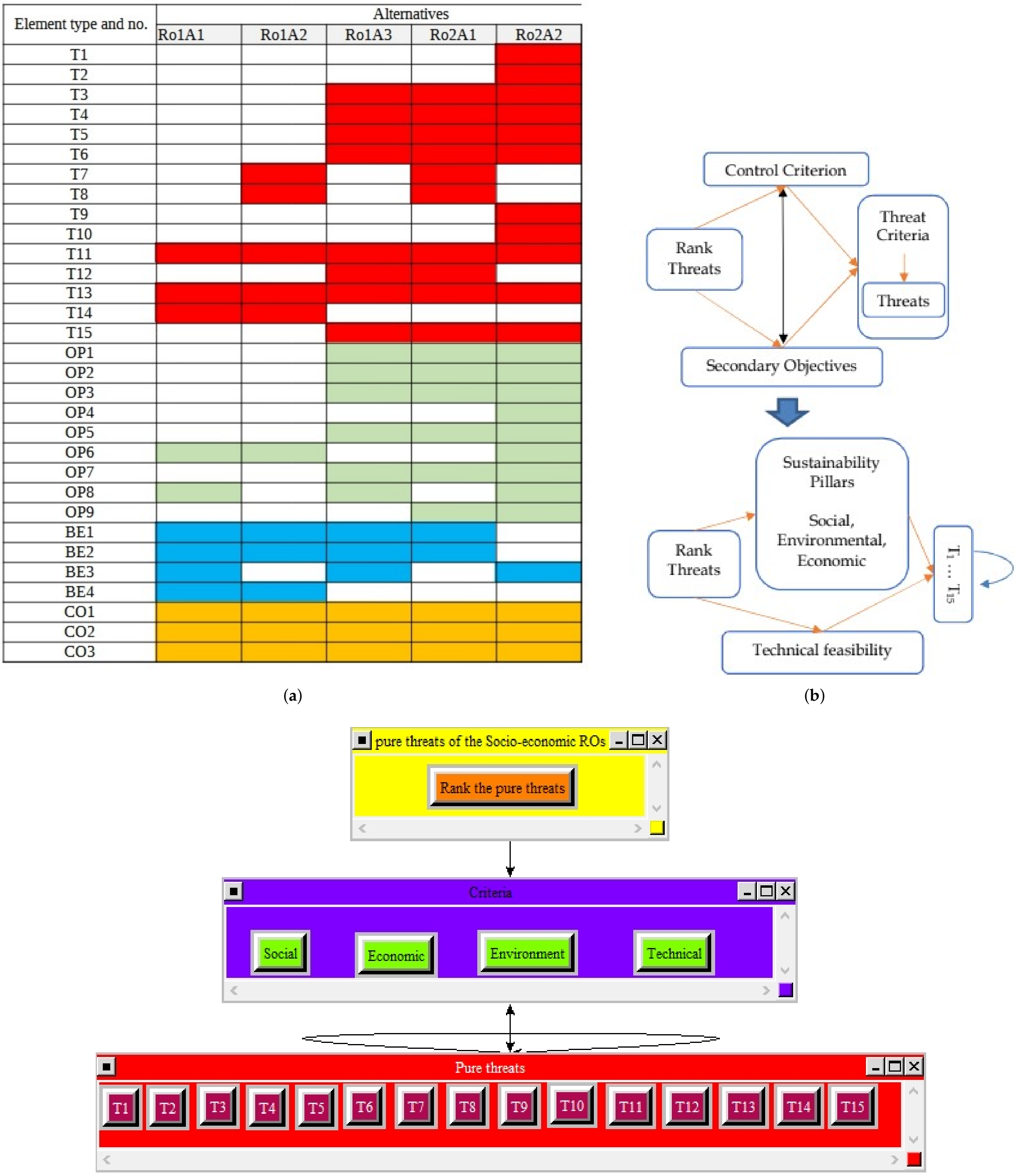
The relation between the T, Co, Be, Op, and the alternatives are shown in Figure 3. The colored box emphasizes a relation between the issue in the Column and the ROiAj in the row. For instance, T1 is a threat that has impact on RO2A2, and RO2A3 . This relation will be used in constructing the network and pairwise analysis of the ANP. Moreover, Alternative no. 5, 8, and 9 were already eliminated in the Step 3 of the current procedure.

3.5.4. Network Construction

In Figure 3, the general Risk network, which refers to pure threats cluster, and the constructed network for ranking the threats regarding the socio-economic transition problem in Super Decisions V3.2 are shown.

3.5.5. Pairwise Comparison

The pairwise comparisons were made through data collected in semi-structured interviews, and the geometric mean of all values were used for building the pairwise matrix. Figure 4 shows both the unweighted supermatrix and the limit supermatrix of the risk network to define the priorities of the pure threats. The final normalized priorities of the elements in the pairwise comparision extracted from unweighted supermatrix. In SuperDecisons software, the output that provide the results called Priorities, wh̀ich are shown in Figure 5.



(**a**) (**b**)

(**c**)

Figure 3. Risk Network of the current study. (**a**) The relation between T, Co, Be, Op and alternatives.(The different colors of this sub-figure is just to make a visual separation); (**b**) Risk Network map; (**c**) The Risk network (Elaborated by Super decision Version 3.2. The colors of this sub-figure are output of the Super Decisions software).

Weighted Super Matrix																						Limited Super Matrix results		
		Criteria				Pure threats																		Pure threats
		Economic	Environment	Social	Technical	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	Rank the pure threats			Rank the pure threats
Criteria	Economic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.064249		Economic	0
	Environment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.106233	Criteria	Environme	0
	Social	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.106233		Social	0
	Technical	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0.723285		Technical	0.297929
Pure threats	T1	0	0	0.034655	0.137056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T1	0.082603
	T2	0	0	0.321675	0.285017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T2	0.171778
	T3	0	0	0.231306	0	0	0	0	0	0	0	0	0	0.888889	0	0	0	0	0	0	0		T3	0.05523
	T4	0	0	0.035167	0	0	0	0	0	0	0	0	0	0.111111	0	0	0	0	0	0	0		T4	0.006904
	T5	0	0	0	0.183268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T5	0.110454
	T6	0.465664	0	0	0.064159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T6	0.038668
	T7	0	0.125	0.055552	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0		T7	0.003724
	T8	0.053636	0.875	0.280392	0.180251	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	Pure threats	T8	0.142155
	T9	0	0	0	0.050962	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T9	0.030715
	T10	0	0	0	0.029769	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T10	0.017941
	T11	0.356465	0	0.024449	0.013687	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T11	0.008249
	T12	0.124234	0	0	0.010742	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T12	0.006474
	T13	0	0	0	0.01548	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T13	0.00933
	T14	0	0	0	0.01548	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T14	0.00933
	T15	0	0	0.016805	0.01413	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		T15	0.008516

Figure 4. Threats unweighted supermatrix (exported from Super Decisions V3.2—the figure illustrates the output of the software, which consists of the limiting super-matrix results and the weighted super-matrix. The weighted super-matrix contains the square matrix of pure threats T1 to T15 along with Criteria).

Name	Graphic	Ideals	Normals	Raw
Be1		0.102929	0.052110	0.022990
Be2		1.000000	0.506275	0.223356
Be3		0.142857	0.072325	0.031908
Be4		0.729426	0.369290	0.162922

(**a**)

Name	Graphic	Ideals	Normals	Raw
T1		0.526833	0.060691	0.047725
T2		0.526833	0.060691	0.047725
T3		0.706088	0.081342	0.063963
T4		0.706088	0.081342	0.063963
T5		0.526833	0.060691	0.047725
T6		0.526833	0.060691	0.047725
T7		0.473167	0.054509	0.042863
T8		1.000000	0.115201	0.090588
T9		0.526833	0.060691	0.047725
T10		0.526833	0.060691	0.047725
T11		0.526833	0.060691	0.047725
T12		0.526833	0.060691	0.047725
T13		0.526833	0.060691	0.047725
T14		0.526833	0.060691	0.047725
T15		0.526833	0.060691	0.047725

(**b**)

Name	Graphic	Ideals	Normals	Raw
Assets (Servers)		0.639619	0.276495	0.121983
Budget		1.000000	0.432281	0.190712
Human resource		0.673693	0.291225	0.128481

(**c**)

Name	Graphic	Ideals	Normals	Raw
Op1		0.077074	0.042966	0.021483
Op2		0.233776	0.130323	0.065162
Op3		0.261652	0.145863	0.072932
Op4		1.000000	0.557471	0.278736
Op5		0.050326	0.028055	0.014028
Op6		0.050326	0.028055	0.014028
Op7		0.000000	0.000000	0.000000
Op8		0.080946	0.045125	0.022563
Op9		0.039715	0.022140	0.011070

(**d**)

Figure 5. Overall priorities produced by Super Decisions Version 3.2). (**a**) Priorities for the Benefits; (**b**) Priorities for the Threats; (**c**) Priorities for the Resources; (**d**) Priorities for the Opportunities.

3.6. Stress and Strain Calculation

Stress and Strain were calculated for each alternative employing the parameters produced in the previous step, and they are reported in the next two subsections.

3.6.1. Stress

Stress is calculated through Equation (7) in Section 3 and the information extracted from the relation table (see Figure 3a). The results are listed in Table 4. In the following the implementation of the Equation (7) is shown for Stress RO1A1. From the table of Figure 3a, the threats which are related to alternative RO1A1 are T11, T13, and T14. The results of ANP in Figure 5 show that the weights of these threats are all equal to 0.060691. Therefore, TW for this alternative is calculated through Equation (7) as follows:

$$\mathrm{TW} = \mathrm{T11} + \mathrm{T13} + \mathrm{T14} = (0.60691 \times 3) = 0.182073$$

$$\mathrm{CW} = (0.276495 + 0.432281 + 0.291225)$$

In the same way and using the results of the ANP analysis in Figure 5, the related resources are Co1 = 0.276495, Co2 = 0.432281, and Co3 = 0.291225; Opportunities are Op6 = 0.028055 and Op8 = 0.045125, and benefits are Be1 = 0.052110, Be2 = 0.506275, Be3 = 0.72325, Be4 = 0.369290. All of the other Stress values in Table 4 are calculated in the same way.

$$Stress\mathrm{RO_1A_1} = \frac{(0.182073) \times (0.276495 + 0.432281 + 0.291225)}{(0.028055 + 0.045125) \times (0.052110 + 0.506275 + 0.72325 + 0.369290)}$$

$$Stress\mathrm{RO_1A_1} = 2.488018$$

Table 4. Stress table.

Alternative	**RO1A1**	**RO1A2**	**RO1A3**	**RO2A1**	**RO2A2**	**RO2A3**
Stress	2.488018	13.51665	2.129059	3.377369	9.801651	12.72224
Normalized stress	0.0565	0.3070	0.0483	0.0767	0.2226	0.2889

While Stress is a dimensionless value, Strain is measured in currency in this study. The amount of Strain for different alternatives could be very different. Therefore, to express all the values of numeric columns in a common scale, we normalize them. These values will be re-scaled to make all the elements lie between 0 and 1 (Table 4). Linear normalization is used to normalize the final Stress and Strain values employing $n_{ij} = r_{ij} / \sum r_{ij}$ (Vafaei et al. 2016).

3.6.2. Strain

The Strain calculation table is shown in Table 5. The costs are in Iranian Rial, the salary is the average salary for an expert with 10 years of experience in the Persian year of 1398. The price of the thermal paper is referred to 7 January 2020; however, this price is subject to high fluctuation due to the fact that it is not produced internally but imported. National Internet cost is negligible in Iran because the National Internet is very cheap in order to encourage companies and users to use National Internet instead of a global system of interconnected computer networks (Internet). The costs in the following table include the cost of establishing a new service and the first month of implementing the service. To calculate the Strain of each alternative Equation (8) from Section 2 is employed.

Table 5. Strain calculation table.

ROs	Cost Calculation	Cost	Strain	Norm.
RO1A1	[80 (cost of SMS in Iran in "Iranian Rial") × 4 (length of the text message regarding the characters that are in the SMS is equal to 4 SMS in Persian) × 2 (for each transaction two SMS is required including customer and vendor) × 31,973 (Average tax in a specific macro zone regarding the results of Chapter 4)] + [2 (switch developer, POS developer) × DS × 160 h (establish new service)+ DS × 20 h (outsourcing coordination and maintenance)]	88,462,720	1.382	0.1732
RO1A2	2 (switch developer, POS develope_r) × DS × 160 h (implementation)	64,000,000	1	0.1253
RO1A3	2 (switch developer, POS developer) × DS × 160 h (establish new service) + DS × 196 h (application support service, CRM and cyber security measures)	103,200,000	1.613	0.2021
RO2A1	[(80 × 4 × 2 × 30,457(successful tax in macro zone)) + Paper receipt price (26,000 (price of each role of the thermal paper) IR / (20 m (length of the role of the thermal paper) / 4.5 cm (minimum of size)) =58.5 IR) × 1472 (unsuccessful tax in macro zone)]+ [2 (switch developer, POS developer) × DS (Developer Salary per hour (DS) = average 40,000,000 IR / 196 h = 200,000) × 160 h (stablish new service)+ DS × 20 h(maintenance per month)]	87,578,592	1.368	0.1715
RO2A2	Paper receipt price × 1472 (unsuccessful tax in macro zone) + 2 (switch developer, POS developer) × DS × 160 h (stablish new service) + DS × 20 h (maintenance per month)	64,086,112	1.001	0.1255
RO2A3	Paper receipt price × 1472 (unsuccessful tax in macro zone) + DS × 20 h (maintenance per month) × DS × 160 h (stablish new service) + 2 × DS × 196 h (application support service, CRM and cyber security measures)	103,286,112	1.614	0.2023

The average value of IRR in 2018: 1 $ = 40,694 IRR Developer Salary per hour (DS) = average 40,000,000 IR / 196 h = 200,000, $Cost_{RO1A1} = (80 \times 4 \times 2 \times 31{,}973) + (2 \times 160 \times 200{,}000) + (20 \times 200{,}000) = 88{,}462{,}720$, $Strain_{RO1A1} = Cost_{RO1A1} / Cost_{RO1A2} = 1.38223$, *Normalized* $Strain_{RO1A1} = Strain_{RO1A1} / \sum_{i=1}^{2} \sum_{j=1}^{3} StrainROiAj$, *The row in yellow (RO1A2) is the cheapest alternative. So, it is chosen Basic Consumption*

4. Results and Discussion

In Figure 6, considering that the vertical axis in the coordinate plane is Strain, the significant high Stress and Strain of the RO2A3 shows that the benefits and opportunities of this alternative do not outweigh its threats and costs; it is very expensive alternative in comparison with the other alternatives. The other alternatives have better performances, so this alternative can be removed from further analysis. Blue and red points show that the transitions from RO2A2 and RO1A2 towards the other alternatives increase the Strain but decrease the Stress. RO2A2 and RO1A3 are cheaper alternatives but they have a high stress. Therefore, RO2A1, RO1A1 and RO1A3 are better to accept; because in comparison with the stress of RO2A2 and RO1A3, imposing some changes and considering the cost of the changes will cause increase of strain, but the Stress decreases sharply and it provides safe condition to accept the ROs.

Since RO2A1 has higher Stress, we focus on the transition from this alternative towards RO1A1 and RO1A3. The Strain of RO1A3 is higher than RO2A1. It points to the fact that with a small amount of higher resource consumption, the Stress of the target alternative will decrease. Nevertheless, the strain of RO2A1 is almost equal to the Strain of RO1A1 and this proves that the cost for establishing the ancillary service of e-Receipt by 'SMS' is almost equal to 'SMS and paper receipt'. The weight of the threats and costs of providing e-Receipt by SMS in case of successful transaction and paper receipt in case of transaction failure is higher than its opportunities and benefits. This Strain and Stress values confirm that providing e-Receipt by SMS in all scenarios is the best alternative. RO1A1 has less Strain than RO1A3; however, the Stress is not significantly higher; this supports the choice of RO1A1 as the best alternative. In this particular case, RO1A2 (the cheapest) and RO2A2 have the lowest resource consumption rate; and RO1A3 has the lowest Stress. However, RO1A1 might be selected regarding the transitions that discussed.

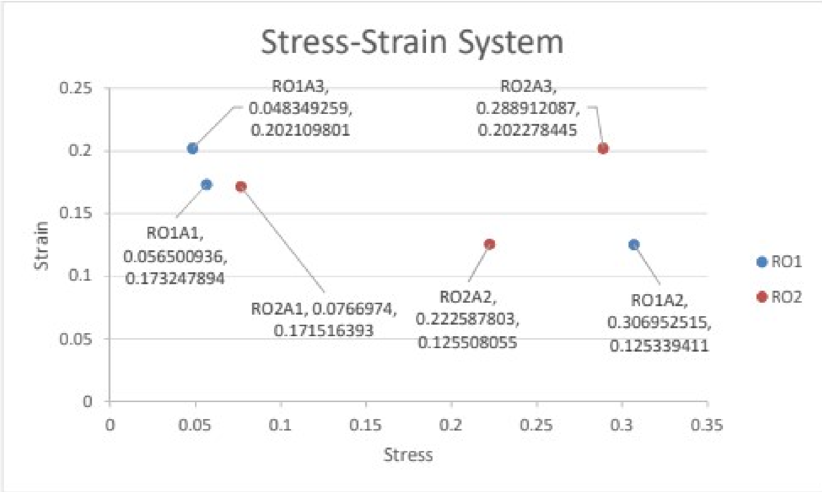


Figure 6. Strain Stress illustration.

Aghazadeh Ardebili et al. (2020) employed TOPSIS in the same case-study. TOPSIS is a well-known MCDM method, and in that study it was used to assess the same alternatives regardless of the uncertainty and possibility of taking the risks. Three main alternatives to the thermal paper receipt were analyzed and ranked. The application of TOPSIS showed that RO1A3 ("Application Notification instead of paper receipt") is the most efficient way for digitalizing the ancillary service of a PSP company that considers sustainability and technical feasibility as evaluation criteria.

5. ROAM Implementation Highlights

The research on planning combined risk response strategies, instead of selecting one strategy out of the four typical risk response strategies (accept, reject, transfer, mitigate), is still rather limited. Further, the existing quantitative methods relate each risk to a single solution and response, and compare it with all other risks. A methodological approach for comparing different solutions relating to a RO, which could bring about different costs and different results in case of accepting the risk, is missing. Lastly but importantly, most of the existing MCDM methods give the highest importance to risk avoidance, and the same weight to other response strategies: this implies that avoiding ROs is the preferred strategy as it can avoid to face the linked threats. The following highlights elucidate some cases where implementing ROAM approach is recommended:

- cases in which the four typical strategies (accept, reject, transfer, mitigate) is not the most effective strategy to deal with a risk, and a combination of measures is needed to exploit the pure benefits and avoid pure threats of a RO;
- cases where the decision-making methods should take into account the effect of changes in a company's risk tolerance, according to different measures to respond to the risk, and the amount of resource consumption for each measure;
- cases where each alternative risk response is compared with other risks and the responses to them. ROAM allows the decision maker to compare different solutions for a risk that could imply different costs and different results if the risk is accepted;
- cases in which the decision maker prefers to consider different weights for different response strategies (most methods neglect the opportunities that can be seized by accepting the risk, and reject the risk after a simple comparison);
- cases where the decision maker is inclined to consider the company's capability of change as a consequence of accepting risk.

6. Limitations and Future Research Directions

The case-study showed a good potential of the ROAM method for supporting strategic decisions of a service company. However, two limitations should be acknowledged in the current study, one related to the data employed and the other to the scarcity of previous studies with which the present proposal could be compared. The data collection was carried out through semi-structured interviews with technical staffs of PSP firms, but all of the interviewees were employed in Iranian PSP firms. In order to generalize the findings, data collection should be extended to include detailed data from international PSP firms. The second limitation is linked to the lack of previous studies in the domain of socio-ecologic transition for PSP companies. The limited literature in the socio-ecologic transition of critical infrastructures unveils the necessity to promote further research in this domain, which could be beneficial for offering more effective tools to manage risks.

To continue this research, the authors of this paper are planning to design a dashboard and a data-oriented decision support system using ROAM. Moreover, even if the original proposal was based on a standard ANP, the employment of a hybrid MCDM method, which could reduce the number of pairwise comparisons, might be taken into consideration. Further, as ROAM method is clearly dependent on the assessments performed by the stakeholders, and some criteria could employ linguistic scales, methods that take into account vagueness should be tested to verify if they can improve the ROAM process and output.

7. Conclusions

Practical sustainable development in CI domain is a multidisciplinary innovative/collaborative approach that ensures a reliable future for next generations besides a resilient future for CI. Digitization of CPSS is a prominent innovative trend, which, in the case of PSP firms, implies the introduction of cutting edge technologies to manage information and, as a side effect, could eliminate thermal papers from the e-payment service life-cycle. Nevertheless, with all opportunities behind socio-ecological, socio-economic, and socio-technical transition, the transition is not free of risk. This study is focused on different alternative ways to eliminate paper receipts from e-payment POS terminals through digitalization. The complexity of the PSP firm as a CPSS and the significance of continuity of functioning of this financial infrastructure, boost the risks of sustainable transformation of a PSP. Therefore, this transition is a RO. The pure threats it will pose, should be considered alongside the unique opportunities. The ROAM method showed a high capacity in dealing with risk-based decisions that should be made in order to establish hazard free service.

The result of using ROAM in the case study discloses that RO1A1 (SMS) is the best alternative to accept because the Stress decreases significantly with small resource consumption, meaning that the risk-taking capability of the company for establishing the ancillary service of providing e-Receipt is higher than that provided by the other alternatives. In a previous work, Aghazadeh Ardebili et al. (2020) employed an MCDM TOPSIS model to assess the same alternatives regardless of the uncertainty and possibility of taking the risks. That model showed that RO1A3 (Application Notification) was the preferable option. This significant contradiction reveals the importance of taking the positive and negative effects in account when the alternatives of analysis are risky-opportunities.

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Conflicts of Interest: The authors have no conflict of interest to disclose. The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

Appendix A. Future Issues

(Risks, Opportunities, Benefits, Costs are categorized and listed)

In the Tables whose links are reported below, the probability is a percentage between 0 and 100, in which 0 means the issue will not happen, and 100 means the issue will certainly happen. The impact is an integer between 0 and 10, in which 0 means the issue has no impact on the project and its goals, and 10 means the issue has an extremely strong impact on the project and its goals.

Information Security is an issue related with security. It has a low probability of occurrence and a very strong impact when one of the alternatives of RO1 is implemented.

Future Issues Table 1: https://drive.google.com/file/d/1QQV1uFY433Tu-CmtE0jf6rbZOfLbU1BK/view?usp=sharing (accessed on 1 June 2020).

Future Issues Table 2: https://drive.google.com/file/d/19qjEarFUT8jFZGsd6QId0KGCfu8-Qs08/view?usp=sharing (accessed on 1 June 2020).

Appendix B. [C, O, B] Clusters

Clusters Tables 1–3: https://drive.google.com/file/d/1fH8ZBvaqdkUWoCqj1Q-28oYOMnXGFeiU/view?usp=sharing (accessed on 1 June 2020).

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