International Journal on Interactive Design and Manufacturing (IJIDeM) (2020) 14:1557–1568
https://doi.org/10.1007/s12008-020-00709-1

TECHNICAL PAPER

Decision-making laboratory for socio-technological systems

David Balderas[1] · Jose Martin Molina Espinosa[1] · Sergio Ruiz Loza[1]

Received: 2 May 2020 / Accepted: 29 August 2020 / Published online: 10 September 2020

Abstract
Most socio-technological Systems are complex and have many variables interconnected, which makes them hard to predict and more important to control. Moreover, in many cases it is required to choose a plan of action that would bring some consequences and/or rewards. Under those circumstances it is important to make a decision based on the system's variables, requirements, munificence and complexity and that they are evaluated using feasibility, viability, key performance indicators and time. In particular, the time required to make a decision. Hence, the correct use of decision-making tools would increase the chance of making a correct choice. For this reason, this work focuses on the list of requirements for a facilitation room, facilitation staff and tools, that would help the stakeholders to make a choice in a timely manner. The work ends with some suggestions that are likely to favor the final decision.

Keywords Decision-Making · Stakeholders · Facilitation · Room · Laboratory

1 Introduction

Systems can be defined as a group of entities that are interconnected [54]. This implies that the entities of a system will either respond to, or be affected from changes to any element of the system. A system, which involves entities of a social and technological nature, becomes a complex socio-technological system [14,59]. These systems have some characteristics in common, such as: multiple entities interrelated with many variables, many possibilities and freedom of operation, particular and general objectives of the entities that compose them and difficult to predict future behavior. Some examples of complex socio-technological systems are healthcare, transportation, government policy implementation, environmental protection and education which have many interactions and have many contributions from different fields to work efficiently [41].

More specific examples of complex socio-technological systems are the cases of the applications Airbnb or Uber, where the technological system is composed of the web application developed to request a room for rent or a transportation system for a certain amount of time or distance, the schemes for collection and administration of time, while the social parts of the system are the house or car owners and users which interact between each other to provide and receive a service [36].

More in detail, as the name suggests socio-technical systems are composed of technological and social factors. The technological factors in complex socio-technological systems are composed of those tools, devices or means, which are used by the human factor to perform some task, satisfy some need or reach an objective. The behavior of the technological factor normally presents patterns or algorithms that in general can be identified and represented with some precision. On the other hand, the social factor cannot be easily measured, and its relationship is not easily understood. Moreover, normally systems consider incorporating technical elements as core and pays no attention to social elements thinking of them exclusively as contextual. However, social elements and the corresponding relations must also be considered as belonging to the system [43], otherwise factors such as social interaction might be forgotten.

One special element of the social factor that is commonly mistakenly excluded is decision-making. This is especially important since is precisely humans who choose the actions within the systems and setup its initial configurations. So,

✉ David Balderas
dc.balderassilva@tec.mx

Jose Martin Molina Espinosa
jose.molina@tec.mx

Sergio Ruiz Loza
sergio.ruiz.loza@tec.mx

[1] Campus Ciudad de Mexico, Tecnologico de Monterrey, Puente 222, Del. Tlalpan, 14380 Mexico, Mexico

decisions are of importance because they incite how a system will react and finally how it will perform on the long term. Hence, humans need to make decisions and must be aware that their choices will alter the social factor, the technological factor or both, in a certain determined time, taking into account the multiple variables that affect it and the multiple objectives within this type of systems. For this reason, facilitating a correct decision-making will help planning and guiding the future of a complex socio-technological system.

It is important to notice that decision-making is likely made considering the opinion of several people or actors that are invested in the outcome. Yet, in many cases these actors are independent, they probably have particular objectives that often contradict each other, have different time restrictions, have different backgrounds, and there is little clarity regarding how to weight the priorities of each member. Another aspect to be considered within complex socio-technological systems is that when different actors act independent, optimization moves away and the system may have the opposite behavior to the desired one [17,54].

Further, the use of interactive spaces are beneficial to avoid frustrations and promote positive experiences (i.e. enjoyment, engagement) [44]. Also, the interactive design changes how people communicate, interact and share information, and impact a large number of sectors, from cultural, manufacturing, creative, education, and healthcare. enabling new attractive opportunities [18,58]. Moreover, the use of screens has been proven to be beneficial to engage actors [51]. These aspects raise the importance of having specific spaces where actors may engage in the decision-making process.

Consequently, this work focuses on the design of room to facilitate decision-making. In the second section decision-making is defined more extensively, coupled with its main differences, variables and tools. After, the third section explains decision-making facilitation, including a room, facilitation staff and storytelling as a useful technique for decision-making. The fourth section introduces a room for decision-making including suggestions for a technological model and specifications for the room and its facilitation staff. Finally, the last section gives context, future work and conclusions on the study.

2 Decision-making

Decision-making is an important component in complex problem solving, like situation assessment negotiation, design, and command and control [38]. There are many kinds of decisions like choosing from a large set of alternatives, accept or reject an option, and constructions which are complex problems that require many choices and compromises to obtain the ideal solutions with current resources [30]. Certainly, decision-making for constructions are not trivial and require that many options be weighted before a decision is made.

Yates [60] defines decisions as a commitment to an action that is designed to yield a satisfying result for many groups. Likewise, Candelas [6] defines it as electing from a simple or complex array of options the one or more that satisfies the criteria along a certain number of perspectives. Further, Jonassen [30] states that a decision is a representation of a problem where the problem-solver assesses from two or more possible outcomes and selects one of the alternatives to follow. In his work he also describes that rationally the best option is the one that provides maximum utility and from a natural perspective is the one with the most agreement with personal beliefs and experiences [30].

Markedly, all these definitions state that is required to select one from a multiple-choice option. Those options are an assemble of requirements, strategies, events, prediction, opportunities which requires a settlement to a plan that might obtain the highest returns or benefits to the involved parties [30]. In general, decision-making involves, at a minimum, the following three processes:

- Problem statement. At this point the problem is clearly identified, the objectives or goals, its limitations and scope.
- Definition of Alternatives to solve the problem or to reach the objective. In this section several alternatives are proposed to solve the problem, identifying its advantages and disadvantages. Each of the alternatives must be evaluated from different perspectives, either be financial, technical, ethical perspectives, among others.
- Most favorable alternative selection. At this point, and the variable that, under the perspective of the decision makers, is the best option is selected. The decision-making processes must consider issues related to legality, ethics, environmental impact and economic valuation, since these aspects may affect the viability of decision made.

As it can be observed these three processes does not include any implementation since it is not a direct process of decision-making, yet, it can be included as feedback to restart the whole process (see Fig. 1).

2.1 Variables and evaluation for decision-making

As stated before, decision-making involves selecting an alternative from multiple options. Commonly, this alternative would be the one with ideal or optimal benefits. In engineering and economics, optimization is based on considering single objective, evaluating criteria or point of view [61]. However, in reality, obtaining the ideal solution requires to

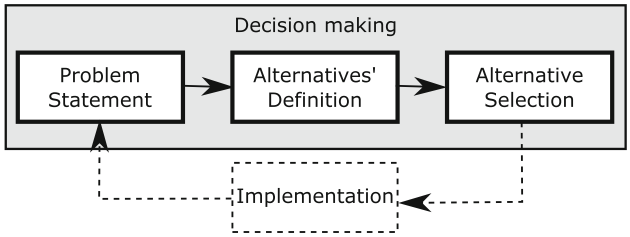

Fig. 1 Decision making processes

take into account various elements or variables for decision-making, however, as previously stated, having many actors moving independently makes the system to move away from optimum [17,54].

For this reason, to make a correct decision it is highly beneficial to observe what are the necessities and how some variables work together (in other words, requirements, munificence and complexity) and evaluate them working together in terms of velocity, feasibility and viability. Additionally, it is not always simple to do so since these variables likely have multiple criteria, conflict between their criteria, are complex, are subjective and ill-structured for the evaluation process, or they require introduction of the decision makers in the evaluation process [50,61]. Some of the most important variables are listed below:

2.1.1 Stakeholders requirements

Typically, a system has many investors that have participation in the process of decision-making. The change from one to multiple decision-makers introduces a considerable amount of intricacy, which changes from the most preferred alternative among similar solutions from one individual, or single decision-maker, to consider the conflict between different interest groups, with particular preferences, ambitions, knowledge, experiences, and criteria [27].

With this in mind, it is important that each decision-maker state their criteria or the goals they are trying to reach through the system. After, from those goals it would be important to see if they match and if they can be obtained with the current and future resources available, with a correct description of the system and in a timely manner.

2.1.2 Munificence

Another variable to consider is munificence, which is defined as the capacity to support sustained growth of an organization [1,9,22] that can be separated in three kinds: capacity or levels of resources available, growth/decline as the change in capacity, and opportunity/threat as the extent of unexploited capacity [7,21]. Observing these factors is important to avoid scarcity of resources that might lead to commit illegal acts or may lead to have negative effects on system performance.

2.1.3 Complexity

One last variable to consider is the system's complexity [9], which is how the system inputs interact and what output they produce. This variable is of importance since knowing how the system works can help predicting a possible outcome and make a decision based on that. However, in many cases it is impossible to know the input-output relationships especially considering that there might be many non-linearities and hence the system might produce strange and counter-intuitive behaviors [25].

Also, as the system complexity may not be fully understood , it might lead to commonly cognitive simplification (selective perception, heuristics and analogies) which may affect strategic decision possibly shortening the list of alternatives [22].

2.1.4 Feasibility and viability

After the variables have been observed it is required to evaluate some factors that would state if it is possible to obtain the goals, and to see if the plan can be deployed. Eisenhardt [12] found that in order to make a successful decision it is required to use more information, see more alternatives, and use a great amount of consultation. Also, that to make a proper decision, it is better to have a good level of comprehension on the process [45].

As previously stated, having multiple investors increases the criteria to consider for decision-making, hence, it is important to take special consideration in its feasibility and viability, which include aspects like engineering, legality, ethics, and, in specific cases, economic viability. These criteria must be evaluated prior to the selection of a decision, since omitting any of them may cause that selected objectives may not to be reached. Under those circumstances it is important to make a vigilant decision and use some criteria that consider how the variables work. Janis [29] proposed criteria for vigilant decision-making:

1. Thoroughly portrait the range of courses of action.
2. Survey full range of objectives and implications.
3. Carefully weigh costs, risks, and benefits of each alternative.
4. Intensively search new information for evaluating alternatives.
5. Correctly assimilate new information.
6. Re-examine positive and negative consequences of each alternative.
7. Plan to include contingencies if various risks might arise.

These criteria can be separated in three [28,57]: (1) the reasons to select an action must be rational, meaning they are unambiguous, understandable, debatable, coherent, and agree with knowledge; (2) the reasons must withstand proper research; and (3) they must consider future uncertainty including contingency plans. Thus, it is essential that before any decision is made all the alternatives and possible outcomes had been properly researched and evaluated.

To make this decision, different types of analysis must be made. For instance, Klein [33] and Goll et al[22] indicate that in order to make rational decisions a quantitative analysis must be made so that it can have a stricter analysis and consequently be more reliable. Another form would be to check for some cues of a cause-and-effect events connections, such as similar behavior or direct relation between variables, spatial or temporal closeness; and likeness in pattern [57].

2.2 Time

Planning is important when making decision that affect the future [20] and affect many areas of decision making (some of them are enumerated in [2]). Mainly, this variable must consider the time it takes to implement, time to finish a resource, to generate an outcome, to evaluate its condition and time to make a decision. Since in many situations choosing the best strategy is irrelevant if it takes too long to formulate [13].

2.2.1 Key performance indicators

Key Performance Indicators, or KPI, are measurable values that show how effectively a company is reaching its key business goals. Companies use KPIs at different levels to trace effectiveness and efficiency. KPIs are specific measures that tell stakeholders whether the organization is attaining its goals using its resources adequately [10]. Some examples of KPIs are sales growth, return/loss, net profit, cost variance, etc.

Rosenau [49] states how fundamental is to have systems of KPIs which provide visibility of performance at different organizational levels and how necessary it is to have coherence between the different perspectives. Furthermore, each KPI must be analyzed separately and then in related groups [46] and most reflect the interests and perception of performance from the different stakeholders [4]. This means that the use of KPIs appears to be essential for a successful decision-making [35].

Additionally, finding relationships between KPIs is likely more profitable if they are projected toward strategic objectives and some existing relationships are found between objectives. Therefore, cause-effect relationships can be made clear and stakeholders would have extra information helpful for decision-making [48].

2.3 Decision-making tools

As previously stated, decision-makers frequently use diagnostic systems in order to observe the cause-effect relation and make a decision. Normally, the first approach is to use quantitative analysis which implies using simulation models for prediction. These models analyze historical information with respect to a specific problem and give a numerical value so that an appropriate decision can be made [6]. There are mainly two types of simulation models: **Deterministic and Stochastic**. Deterministic models have a direct effect of input-output variables and always produce the same output. Using this deterministic causality, a specific system is analyzed to evaluate the effect of a decision on it [42]. On the other hand, stochastic models use probability theory to determine how likely a certain event will occur and use this information for a better decision-making. It is important to mention that statistical models do not indicate a direct course of action, how an event unfolds will depend on the decision maker and chance [6].

Albeit quantitative analysis is normally preferred, it cannot always be created. Furthermore, in many cases, it lacks information about qualitative factors and needs that are guided by feelings and beliefs. There are alternative methodologies to predict the output of a system. The following points address some of the main methodologies and tools for decision-making:

2.3.1 Brainstorming

It is s an auxiliary technique in the decision-making process, that is commonly used when the decision is made by a large group of people. Each one of the of the members of the decision makers group proposes an idea, which will generate multiple alternatives. Then, these ideas are passed to a phase of analysis, discussion and selection of the best, after being evaluated by the group, the most convincing is chosen to solve the problem in question [23].

2.3.2 TILMAG

The TILMAG technique (the transformation of ideal solution elements in an association matrix by its German acronym), was developed by Helmut Schlicksupp [53] and is a technique based on the association of "ideal" decisions that lead to the best possible solution [23]. In general, the TILMAG technique uses a matrix which uses ideas that are not related and make associations that could create future improvement by combining them.

2.3.3 Devil's defense technique

This technique is usually implemented where the decision is made in a group manner to critically analyze a favored decision. In this technique, a member of the group is selected to play the role of the "devil's advocate", who will be in charge of identifying the disadvantages that a decision might have, thereby achieving an awareness of the risks of the decision [19,54].

2.3.4 Delfos technique

This is a specialized technique in decision-making where a large number of people intervene, in which the problem, objective or situation is first established, after, a group leader elaborates a series of questions focused on reaching a decision. Later, each of those involved in the decision write their answers to the questions, who, in conjunction with the group leader, summarize the answers and sends the results with new additional questions to the decision makers, who again respond and the process is repeated until reaching a decision convenient for the group [19].

2.3.5 Decision trees

This tool helps in the decision-making process by allowing to chronologically represent the implications of a decision. This tool favors to evaluate the future implications of making a decision or others, its use is very common in making financial or manufacturing decisions [47].

2.3.6 Ishikawa's diagram

The Ishikawa diagram or fish bones is a tool used in decision-making processes that recognize, through a brainstorming, which are the possible causes of a particular problem or situation, by means of a graphical placement of the ideas collected from the group ordered by theme. [15].

2.3.7 Cause-effect diagrams

The cause-effect diagram is a technique that allows to graphically identify the causes or consequences of a given phenomenon, as well as helping to establish relationships between these phenomena [16].

2.3.8 Experience

Decision makers often use, in their decision-making processes, the experience and knowledge they have acquired throughout their professional career to evaluate and select the best alternative.

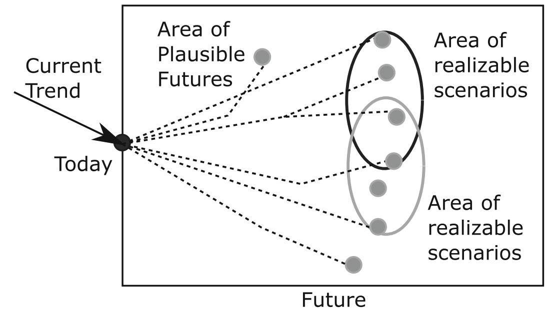

Fig. 2 Realizable scenarios. Adapted from [20]

3 Decision-making facilitation

All these variables, models and techniques of evaluation requires a place or room where they can be discussed. The room must provide the affordance to simulate multiple environments, aid in expressing the different ideas from stakeholders and make a cost-benefit analysis work. Consequently, this room may become a helpful instrument for supporting decision-making.

Scenarios can be divided in following categories [20]:

- possible scenarios, all that can be imagined.
- realizable scenarios, all that can be accomplished with the constraints.
- desirable scenarios, all scenarios that fall into possible, and appeal to the actors, but that may not be realizable.

It is obvious the chosen scenario falls within the intersection of the desired and realizable scenario as shown in Fig. 2. Hence, it is important to portrait different scenarios, analyze them and choose the preferred one from that intersection.

In his work Sibbet [55] states that a visual decision room should manage to place both the criteria and the options visible, that the habitat allows an easy way to move options around to determine priorities using "what-if" thinking to conceive multiple scenarios and visualize the impacts, and finally, that it creates a place where a whole group of participants can engage in sessions of decision-making sessions.

Sibbett [55] also states that a dedicated room for decision-making must have three characteristics: (1) abundant space for visualization, (2) excellent technical infrastructure, and (3) facilitation staff. The first requires the use of space where many visualization elements are present as well as a place where various people can write something down.

The second is a place to display electronic information, such as presentation, graphs and/or computerized drawings. In here, it is essential that the graphic information is relevant, suitable, and appealing, otherwise it might become distracting and may take more cognitive processing time to relate to them [3,37,39,56]. Moreover, it is important that the information is spaced and decomposed to facilitate its understanding [37,56].

The third requires the facilitator to be able to work with different kinds of technology for planning and model solving. Also, it is important that the output graphs are presented by the facilitator, since he or she would help using other channels to focus and remember what is important [34,55,56]. Furthermore, since much information is spaced and decomposed, it is necessary to have some delivery timing granting the participants some processing time [37,56].

3.1 Decision-making room

In his work, Sibbett [55], compares a decision room to a play, where diverse areas of the stage are used to interpret parts of the play. For instance, on the left a narrator can be set, who will be the starting focus of attention and gives the background to the play. Accordingly, the middle and right might be used to present two different situations where the main activity can be happening in the center and some secondary scene or development could be placed on the right. Thus, using smart design, stage and light, the public can perceive an impression of location and space.

Using this idea, Sibbet [55] proposes to use the different parts of the room for thinking and planning processes, which might result in giving context and conceive new circumstances. With this in mind, one wall can be used for background information, a second wall could have the opportunities, and a third wall can have the purpose to contemplate the future. Using this versatility and flexibility can help stakeholders to make difficult decisions, like investing limited funds in technologies, infrastructure, new products and to cut costs [55].

Notably, a decision-making room, can use a similar arrangement using one stage which provide managers with a place to give a background and explain how the variables are related on the left, and provide them with the main and secondary possible outcomes in the center and the right part of the stage correspondingly. Also, using a similar setting, might provide a shared recollection of what has happened or has been discussed, avoiding long debates over previous perceptions which might grant the members a faster consensus.

3.2 Facilitator

A decision, to be sustainable, must reflect the needs of each of the stakeholders, which are frequently different. The use of a facilitator benefits in certain areas such as [32]:

- relate the main problems of the stakeholders.
- ease the communication
- keep track of the different opinions
- mediate between misunderstandings
- lead consensus to agree on a criterion

With respect to communication, the facilitator must be a third actor with good communication and listening skills, who can relate all the stakeholders, by encouraging them to interact, making them feel secure so they can speak up [32]. According to Buttler et al. [5] the facilitator must take care of the time, guide the process, and alter techniques, however, should not give his personal opinions, dominate or lead the discussion. Similarly, Niederman [40] states that a good facilitator has good communication skills, understands the group, provides egoless facilitation, is flexible, understands the group objectives, provides leadership and is focused on the task at hand.

Another important factor of the facilitator is to ensure that technology is available to group members so they can concentrate on the group's task contents [24]. In this case the facilitator must be familiar with the use of the technology implemented, create comfort and help on the understanding of the technology outputs, while understanding its capabilities, according to Clawson et al. [8]. Therefore, the main purpose is to make the implemented technology accessible to the decision makers and to facilitate its understanding.

A final characteristic relevant of the facilitator is to be an authority (or power) figure, which could be either *legitimate*, *expert* or *status* [24]. In the first case, the facilitator's legitimate authority is explained as the capability to reward or punish, whence, the facilitator has the right to structure the group's work. In this case legitimate authority grants the facilitator control on how things happen, by directing how group members interact, administrating the meeting schedule, and selecting the techniques that are used.

Similarly, *expert* authority occurs when one member has knowledge that others do not possess [24]. Group members give experts authority since they are expected to know best, and not following their expertise might result in negative consequences.

Lastly, the final form of authority is *status* which might be a side effect of legitimate or expertise power, or tenure within the organization. Status adds reliability to the facilitator opinion, hence, giving power even in areas where the facilitator is not an expert [24].

3.3 The use of storytelling for the decision-making room

One common method for decision making is constructing stories [30], made of scenarios which form relationships of past, present and future events. Cambridge Dictionary defines scenario as *a description of possible events in the future* or in business as *one of several possible situations that could exist in the future* [52]. In decision-making, scenarios are stories that describe future events that occur due to cause-effect relationships [31]. The use of scenarios is highly beneficial to asses long-term outcomes, for example predicting what would be the change of gas price using the information about how much the stakeholders would invest, the feasibility and viability of new plants, the velocity of a plant to be constructed, the complexity of relationships (i.e. energetic and industry consumption), and the munificence of being able to extract this product (old and new deposits).

Scenarios utilize forecasting as an organizational manual for decision-making [11]. For example, a lack of rain is forecast for next year and the government reduces the supply of water to ration. These scenarios require to have a cause-effect story that forecast the outcomes of different iterations. Kant [31] describes a scenario as something that suggests a possible future, from a single selection of cause-effect actions and events, that are limited and evaluated depending on probability.

According to Jonassen [30] a scenario must be built based on identifying the most important external factors and level of uncertainty. This should be followed by constructing multiple stories that produce causally related outcomes, while identifying possible interfering events probability and impacts. Also, by determining how each different story may influence strategic planning and decision making within the organization.

Hence, scenarios can be used to argue or evaluate a decision based on feasibility and viability. Jonassen [30] provides some guides on how to evaluate the creation of scenarios:

- All factors, states, conditions and interconnections are identified with their assumptions supported by evidence.
- All predictions are based on the factors states and conditions and they are plausible.
- Intermediate events, actions, and consequences plausible.
- Interfering events, probabilities and impacts plausible.

In some way these guides states that it is necessary to be able to correctly predict what is going to happen, which is not an easy task. Hence it many cases it would be important to be able to simulate different scenarios to have a better view of plausible consequences, events, and impacts.

4 Proposed room

To sum up, some of the aspects required in the decision-making are as follows.

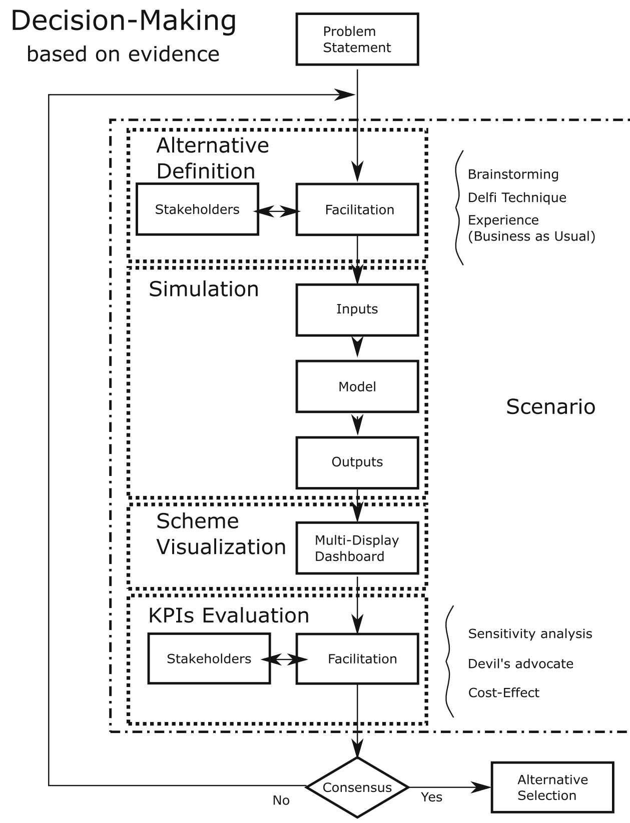

Fig. 3 Decision-making model

- involve stakeholders
- considers the munificence and complexity of the systems
- carefully examine feasibility and viability
- make use of decision-making tools
- uses the room areas to facilitate
- make use of technical infrastructure
- the session is guided by a facilitator which has a form of authority
- uses storytelling with scenarios for forecasting

Hence, the model in Fig. 1 can be elaborated and some steps can be included. The model and extra steps are explained as follows.

4.1 Proposed model

The main idea is the use of different scenarios established by various initial conditions selected by the stakeholders. With this information a simulation runs, providing the results to evaluate if the KPIs obtained are the basis for consensus. After several scenarios are portrayed a consensus can be made and an alternative can be selected. This is represented in Fig. 3.

Before elaborating on each of the steps it is important to realize, that there are two types of variables: endogenous and exogenous. The endogenous are intrinsic to the system, thus, they must be previously investigated and established (e.g. limits of resources, production capability, energy available). These variables are normally set before hand by the facilitator. On the other hand, the exogenous variables are the ones that would change each scenario. Notably, both variables can be modified to simulate different scenarios. For example, an exogenous variable in the electrical model is the peso-dollar parity, since it does not depend on the model, this variable can vary to represent different economic scenarios. On the other hand, the electricity production capacity is a variable of the model, it is endogenous, and it can also be considered as input, since we could assume several production scenarios. For this reason, they require to be analyzed before and after each scenario.

Problem statement

This is a previous step before the whole process of decision-making starts. This step is critical, since the problem is properly elaborated, further investigated and the evaluation KPIs are selected. After, the facilitator must create a model using all the researched information which will become the base for all scenarios.

Alternative definition

Foremost, after the problem has been established, it is important to have a clear idea of what is happening and what variables to use. In this step, the facilitator must explain what is going to happen and with the help of the stakeholders elaborate an alternative. At this point the facilitator can use experience to set historical scenarios as first runs (business as usual) to give context and make the stakeholders aware of the capability of the model. Later, for forecasting, some techniques as Delphi, Brainstorming or other can be implemented to select the settings that would be inserted into the simulation.

Simulation

Once the configuration has been selected the input variables are adjusted accordingly and filled in the model. In this step, using the stage analogy, the left part of the stage can be used to give background to the play. Comparatively, in the decision-making room the left can be used to insert the initial values as framework for the scenario.

After the model has been executed it will produce several outputs and some of them will not be useful raw. Therefore, they must be prepared for further inspection.

Scheme visualization

In this step the most relevant variables had to be presented by means of tables and graphs. For presentation, they are to be further divided into multiple displays using different levels of importance. Following the stage analogy, the most important outputs can be presented in the middle, while secondary outputs (or secondary plots) can be shown on the right.

KPIs evaluation

Then, to further elaborate on the analysis the various KPIs can be evaluated and examined using decision-making tools provided by the facilitator. In this step, the facilitator again can use decision-making techniques that would further elaborate on the analysis. For instance, the facilitator can play the role of the devil's advocate of one of the KPIs helping the stakeholders see its benefits. Or they can observe how the KPIs are related so, in a different run, another scenario can be selected.

Consensus

Subsequently a decision can be made if the alternative is the one that is desired. A key point here would be to return to alternative definition to start various scenarios and the one with must compelling evidence (satisfies the KPIs better) is selected.

Alternative selection

The final step would be selecting an alternative for implementation. In this step the facilitator requires to document the whole process and final decision for future reference.

This model requires that the different actors (stakeholders, facilitator, simulation model and stage) intervene. Figure 4 provides with a road map of the intervention of the main concern elements of the decision-making process. This figure is included to give context on the different components and what are their tasks at different moments of the decision-making process.

4.2 Proposed room specifications

As a proposal, using the analogy of a stage, the room for decision-making will use a wall as the main stage. On this wall, future representations of different scenarios can be projected using a computer and multiple displays. This main stage can be divided in three, with the left as the area to give context (set input variables to the model), the middle as central stage to give the main possible outcomes of the decision, and the right for other possible outcomes of the decision.

Notably, the proposal has multiple displays, there are mainly two reasons behind this decision: First, although a single screen can be used, the size would make the price to be high and could not be easily adjusted. And second, the use of multiple monitors help to separate the stage into sections which can show different aspects required for decision-making and can be setup according to the number of stakeholders present in the meeting.

	Stakeholders	Facilitator	Model	Main Stage
Problem Statement	KPI Definition	Model Creation		
Business as usual			Expert scenario	Show expert Results
Alternative Definition	Elaborates on alternatives	Implements Decision-making Techniques		Display Current Scenario
Simulation		Set input scenario	Run Simulation	Display Current Scenario
Scheme Visualization		Selects Tables or Graphs to show		Display New Scenario
KPIs evaluation	Discuss Alternatives	Implements Decision-making Techniques/ change Tables or Graphs		Display New Scenario/ Graphs can be modified
Consensus	Take decision about current scenario	Leads selection process and Restarts scenarios or ends decision-making process		
Alternative Selection		Reports meeting and Consensus		Stores final scenario for implementation

Fig. 4 Decision-making road map

Continuing with the analogy, it is worth noticing that the main stage can be divided in any odd number of displays to have a left area to give context, a central area for the main focus, and right area for other possible situation or outcomes (see Fig. 5 left).

While adding more screens might be increase the visualization space of the center area, it also reduces the lateral stages (Fig. 5 center). A good comprise of these features can be achieved with seven or more displays (Fig. 5 right), where the central area is increased, while the other two are just slightly reduced.

Using this configuration, there could be two input screens, three main output and two auxiliary output screens. What this configuration also provides is the possibility of having three input screens, two main output screens and two auxiliary screens and yet, the main screen or focus would not be lost (see Fig. 6).

Another recommendation is that the chairs and tables are not fixed and can be moved around. Using moving chairs and tables would be helpful for different aspects of the decision-making process. For instance, a herringbone configuration can be used for the story telling, while a horseshoe or round configuration can be helpful for alternative definition of KPIs evaluation, using any decision-making technique (See Fig. 7).

4.3 Proposed facilitator specifications

In the proposal, it is recommended that instead of having just one facilitation member it would be important to have a facilitation staff. This suggestion is based on the fact that most socio-technological systems have complex relationships that require vast knowledge on the subject to be discussed. Further, the technological implementation to intertwine all the variables for the simulation would be complex and would require that the proposed room has several technological components and requires to have programming experience to create a good simulation. Furthermore, the facilitator must mediate all the participants using several decision-making techniques while keeping record of the meeting. Therefore, having just one facilitation member would be overwhelming.

As an alternative, a staff can deal separating the main task and assisting the main facilitator for the process. One part of the staff would take care of the room, assisting with technology (screens, audio, video, lights, etc.), space (such as chair orientation), keeping record of the meeting and most importantly, take care of managing the simulation execution that would forecast different scenarios.

Consequently, the main facilitator can take care of leading the meeting and facilitating the understanding of scenarios and techniques. Markedly, this is not a simple task, since it is still important that the main facilitator is a power figure (legitimate, expert or status) has knowledge on how the technology, main stage and room are used for configuring a scenario and make simple modification. And finally, has

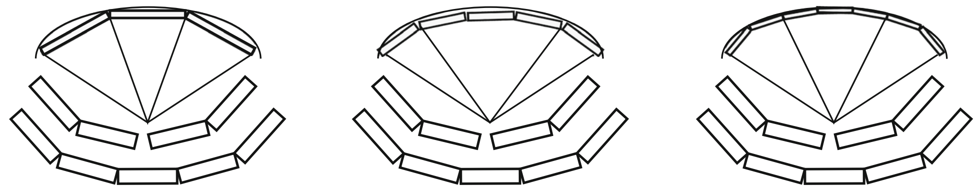

Fig. 5 Decision-making main stage

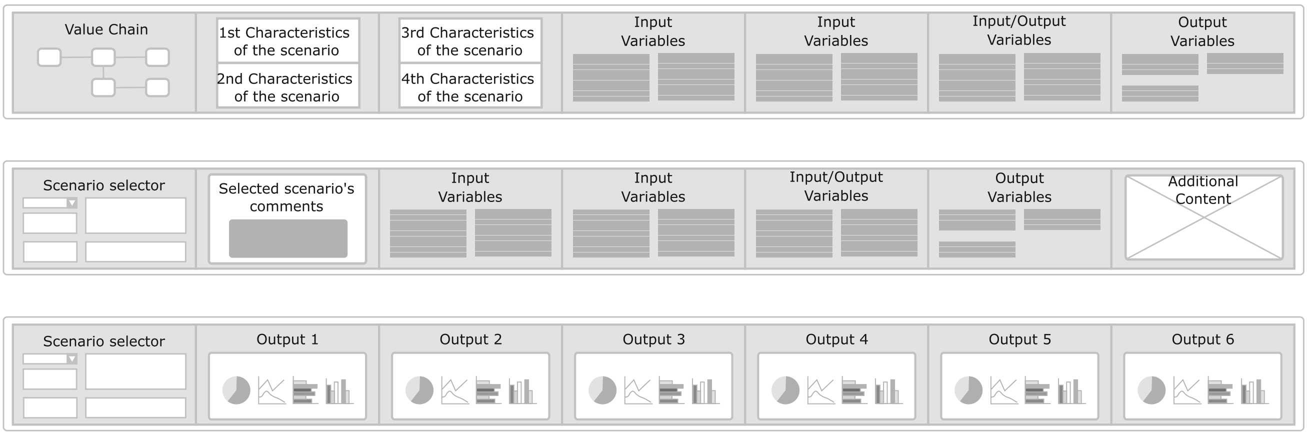

Fig. 6 Storytelling

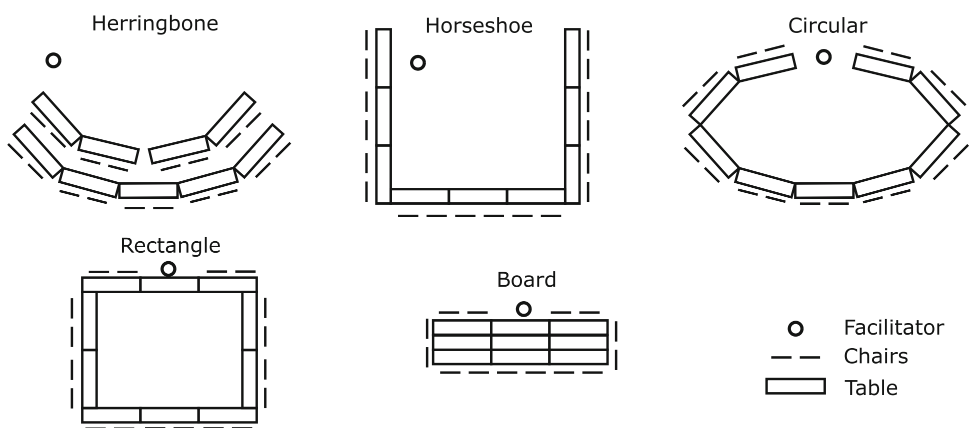

Fig. 7 Decision-making tables

knowledge of decision-making techniques that work well with scenarios and can create a proper environment for them to work correctly.

5 Conclusions and future work

Most socio-technological problems are complex and difficult to understand in full. Currently, decision-makers must deal with many variables as part of their endeavors. Assessing the evolution of socio-technological problems in all their conditions, helps as a guide for decision-makers to choose their approach to solve them. However, in many cases the evaluation of these conditions is characterized by a complex interaction between the stakeholders, the system's variables and their interrelations.

The use of scenarios offers an alternative to have a picture of present and future events. Using them correctly may improve understanding and anticipation of the future and might be helpful for groups to start moving into a certain direction. Furthermore, the adoption of computational technologies in the decision-making processes makes it possible to streamline decision-making sessions by analyzing a large amount of information in real-time.

Consequently, the proposal includes a room, which integrates the different variables, their interrelation and evaluation. It also uses technology and scenarios as tools to help on the decision-making process. By making use of diverse techniques a simulation can be started, and with its predicted information a more elaborated decision can be made. This process can be repeated to form several different scenarios that would increase the knowledge and make a likely better decision.

Moreover, the use of a facilitator staff can help ease the decision-making process avoiding that the stakeholders are swamped in a mass of irrelevant details and information. And by correctly using the technology, they can display information according to the decision-makers' interests and preferences.

The decision-making room was designed to promote the interaction among the diverse subjects that make up a specific complex socio-technological system to solve problems associated with them through a decision-making process in conjunction with mathematical models that, through of computer systems for visualization, allow to show the impact of decisions over time.

The room's limits still required to be addressed, hence, it is important that future research conduct experiments on how helpful it really is. For instance, involvement of an expert in decision-making information visualization to optimize the display of graphics and settings. Also, it requires to use conducting focus groups to aid in the understanding of how different visual environments improve understanding, responses and facilitate the decision-making for the participants.

All in all, it is believed that the room provides stakeholders with a tool beneficial to the whole process of decision-making, nevertheless, the proposal only gives recommendations which are expected to be used and adjusted according to the necessities of the stakeholders and facilitation staff.

Finally, the room could be employed for interactive learning since it has the potential to engage and draw the attention of learners [18,26]. Also, using the multiple screens, some students will learn better and faster with the help of interactive media that incorporates images, graphics, videos and audio elements [51,58].

Acknowledgements This work was supported by the "Fund for Energy Sustainability CONACyT-SENER" (Fondo Sectorial CONACyT-Secretaría de Energía-Sustentabilidad Energética) under Grant 266632 "Bi-national laboratory for the intelligent management of energy sustainability and technological education, and Tecnológico de Monterrey, Campus Ciudad de México.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Aldrich, H.: Organizations and Environments. Stanford University Press, (2008)
2. Ariely, D., Zakay, D.: A timely account of the role of duration in decision making. Acta Psychol. **108**(2), 187–207 (2001)
3. Atkinson, C.: Beyond Bullets Points: Using Microsoft® Office Powerpoint® 2007 to Create Presentations that Inform, Motivate, and Inspire. Microsoft Press, (2007)
4. Barclay, C., Osei-Bryson, K.M.: Project performance development framework: An approach for developing performance criteria & measures for information systems (is) projects. International J. Prod. Econ. **124**(1), 272–292 (2010)
5. Butler, C.L., Rothstein, A.: On conflict and consensus: A handbook on formal consensus decisionmaking. Citeseer (2007)
6. Candelas, E., Hernández, F., García, M., Montero, G., García, M., García, M.: Fundamentos de administración (2012)
7. Castrogiovanni, G.J.: Environmental munihcence; a theoretical assessment. Acad. Manag. Rev. **16**(3), 542–565 (1991)
8. Clawson, V.K., Bostrom, R.P.: driven facilitation training for computer-supported environments. Group Decision Negot. **5**(1), 7–29 (1996)
9. Dess, G.G., Beard, D.W.: Dimensions of organizational task environments. Administrative science quarterly pp. 52–73 (1984)
10. Dolence, M.G., Norris, D.M.: Using key performance indicators to drive strategic decision making. New Dir. Inst. Res. **1994**(82), 63–80 (1994)
11. Einhorn, H.J., Hogarth, R.M.: Prediction, diagnosis, and causal thinking in forecasting. In: Behavioral decision making, pp. 311–328. Springer, Berlin (1985)
12. Eisenhardt, K.M.: Making fast strategic decisions in high-velocity environments. Acad. Manag. J. **32**(3), 543–576 (1989)
13. Eisenhardt, K.M.: Speed and strategic choice: How managers accelerate decision making. Calif. Manag. Rev. **32**(3), 39–54 (1990)
14. Emery, F., Trist, E.: Soc.-Tech. Syst. **2**, 83–97 (1962)
15. Escalante, E.: Seis sigma metodología y técnicas. México. Ed. Limusa pp. 29–78 (2003)
16. Galgano, A.: Los Siete Instrumentos de la Calidad Total. Ediciones Diaz de Santos, (1995)
17. Galluccio, S., Bouchaud, J.P., Potters, M.: Rational decisions, random matrices and spin glasses. Phys. A: Stat. Mech. Its Appl. **259**(3–4), 449–456 (1998)
18. Garay-Rondero, C.L., Calvo, E.Z.R., Salinas-Navarro, D.E.: Experiential learning at lean-thinking-learning space. International J. Interact. Des. Manuf. (IJIDeM) **13**(3), 1129–1144 (2019)
19. George, J., Jones, G.: Administración contemporánea. Editorial Mc Graw Hill, México (2006)
20. Godet, M., Roubelat, F.: Creating the future: the use and misuse of scenarios. Long Range Plan. **29**(2), 164–171 (1996)
21. Goll, I., Rasheed, A.A.: The moderating effect of environmental munificence and dynamism on the relationship between discretionary social responsibility and firm performance. J. Bus. Ethics **49**(1), 41–54 (2004)
22. Goll, I., Rasheed, A.M.: Rational decision-making and firm performance: the moderating role of the environment. Strateg. Manag. J. **18**(7), 583–591 (1997)
23. González, E.: Nuevas herramientas para la generación de ideas. https://www.aec.es/c/document_library/get_file?uuid=b93d6a13-5b18-4bbe-937e-a6a5d5dab5e5&groupId=10128 (2011). Accessed: 2015-09-30
24. Griffith, T.L., Fuller, M.A., Northcraft, G.B.: Facilitator influence in group support systems: Intended and unintended effects. Inf. Syst. Res. **9**(1), 20–36 (1998)
25. Helbing, D.: Managing Complexity: Insights, Concepts, Applications. Springer, Berlin (2007)
26. Herrera, L.M., Pérez, J.C., Ordóñez, S.J.: Developing spatial mathematical skills through 3d tools: augmented reality, virtual environments and 3d printing. Int. J. Interact. Des. Manuf. (IJIDeM) **13**(4), 1385–1399 (2019)

27. Hwang, C.L., Lin, M.J.: Group decision making under multiple criteria: methods and applications, vol. 281. Springer, Berlin (2012)
28. Janis, I.L.: Crucial Decisions: Leadership in Policymaking and Crisis Management. Simon and Schuster, (1989)
29. Janis, I.L., Mann, L.: Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment. Free Press, (1977)
30. Jonassen, D.H.: Designing for decision making. Educ. Technol. Res. Dev. **60**(2), 341–359 (2012)
31. Kahn, H.: On Escalation: Metaphors and Scenarios. Routledge, (2017)
32. Kaner, S.: Facilitator's Guide to Participatory Decision-Making. Wiley, New York (2014)
33. Klein, G.: Sources of power: How people make decisions. 1998. MIT Press, ISBN **13**, 978–0 (1998)
34. Leahy, W., Chandler, P., Sweller, J.: When auditory presentations should and should not be a component of multimedia instruction. Appl. Cogn. Psychol.: Off. J. Soc. Appl. Res. Memory Cogn. **17**(4), 401–418 (2003)
35. Marques, G., Gourc, D., Lauras, M.: Multi-criteria performance analysis for decision making in project management. Int. J. Project Manag. **29**(8), 1057–1069 (2011)
36. Martin, C.J.: The sharing economy: A pathway to sustainability or a nightmarish form of neoliberal capitalism? Ecol. Econ. **121**, 149–159 (2016)
37. Mayer, R.E., Moreno, R.: Nine ways to reduce cognitive load in multimedia learning. Educ. Psychol. **38**(1), 43–52 (2003)
38. Means, B., Salas, E., Crandall, B., Jacobs, T.O.: Training decision makers for the real world. (1993)
39. Moere, A.V., Purchase, H.: On the role of design in information visualization. Inf. Vis. **10**(4), 356–371 (2011)
40. Niederman, F., Beise, C.M., Beranek, P.M.: Issues and concerns about computer-supported meetings: the facilitator's perspective. MIS Quarterly pp. 1–22 (1996)
41. Norman, D.A., Stappers, P.J.: Designx: complex sociotechnical systems. She Ji: J. Des. Econ. Innov. **1**(2), 83–106 (2015)
42. Ohnari, M.: Simulation Engineering. IOS press, (1998)
43. Ottens, M., Franssen, M., Kroes, P., Van De Poel, I.: Modelling infrastructures as socio-technical systems. Int. J. Crit. Infrastruct. **2**(2–3), 133–145 (2006)
44. Preece, J., Sharp, H., Rogers, Y.: Interaction Design: Beyond Human-Computer Interaction. Wiley, New York (2015)
45. Priem, R.L., Rasheed, A.M., Kotulic, A.G.: Rationality in strategic decision processes, environmental dynamism and firm performance. J. Manag. **21**(5), 913–929 (1995)
46. Pritchard, C.L., PMP, P.R., et al.: Risk Management: Concepts and Guidance. Auerbach Publications, (2014)
47. Quinlan, J.R.: Decision trees and decision-making. IEEE Trans. Syst. Man, Cybern. **20**(2), 339–346 (1990)
48. Rodriguez, R.R., Saiz, J.J.A., Bas, A.O.: Quantitative relationships between key performance indicators for supporting decision-making processes. Comput. Ind. **60**(2), 104–113 (2009)
49. Rosenau, M.D., Githens, G.D.: Successful Project Management: A Step-by-Step Approach with Practical Examples. Wiley, New York (2011)
50. Roy, B.: Des critères multiples en recherche operationnelle: pourqoi? Laboratoire d'Analyse et Modélisation de Systèmes pour l'Aide à la Décision (1987)
51. Salcedo, R.M., Espinosa, M.C.E.: Effectiveness of using smart tvs for teaching engineering. Int. J. Interact. Des. Manuf. (IJIDeM) **13**(4), 1469–1483 (2019)
52. Scenario: Cambridge academic content dictionary. https://dictionary.cambridge.org/us/dictionary/english/scenario
53. Schlicksupp, H.: Kreative Ideenfindung in der Unternehmung: Methoden und Modelle. de Gruyter (1977)
54. Sherwood, D.: Seeing the forest for the trees: a manager's guide to applying systems thinking. Nicholas Brealey Publishing, (2011)
55. Sibbet, D.: Visual Leaders: New Tools for Visioning, Management, and Organization Change. Wiley, New York (2012)
56. Strauss, J., Corrigan, H., Hofacker, C.F.: Optimizing student learning: examining the use of presentation slides. Market. Educ. Rev. **21**(2), 151–162 (2011)
57. Van Der Heijden, K.: Scenarios and forecasting: two perspectives. Technol. Forecast. Soc. Change **65**(1), 31–36 (2000)
58. Violante, M.G., Vezzetti, E., Piazzolla, P.: Interactive virtual technologies in engineering education: Why not 360 videos? Int. J. Interact. Des. Manuf. (IJIDeM) **13**(2), 729–742 (2019)
59. Walker, G.H., Stanton, N.A., Salmon, P.M., Jenkins, D.P.: A review of sociotechnical systems theory: a classic concept for new command and control paradigms. Theor. Issues Ergon. Sci. **9**(6), 479–499 (2008)
60. Yates, J.F.: Decision Management: How to Assure Better Decisions in Your Company, vol. 29. Wiley, New York (2003)
61. Zopounidis, C., Doumpos, M.: Multi-criteria decision aid in financial decision making: methodologies and literature review. J. Multi-Criteria Decision Anal. **11**(4–5), 167–186 (2002)