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An Investigation on the Effectiveness of a Problem Structuring Method in a Group Decision-Making Process

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ABSTRACT

AN INVESTIGATION ON THE EFFECTIVENESS OF A PROBLEM STRUCTURING METHOD IN A GROUP DECISION-MAKING PROCESS

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There is no shortage of methods to address messy problems. A messy problem is a system of problems with multiple stakeholders who may hold different views of what is feasible or desirable. Decision-makers in a messy problem are prone to committing an error – especially the Type III error. One of the ways to mitigate the chance of committing the error in a messy problem is to reach a group consensus. Problem Structuring Methods (PSM) are the collections of participatory modeling methods that aim to tackle a messy problem. Despite the positive reports, literature indicates some challenges and criticisms of the effectiveness of PSM applications. One of the main challenges is the difficulty in identifying clear benefits which leads to a lack of interest from a wider community – particularly in the U.S. This study empirically investigates the effectiveness of a PSM in a messy problem to address the present challenges. Confidence can be a proxy to indicate that a group consensus is reached in a messy problem. Experimental research was conducted to assess participants' problem-solving confidence in a messy problem. The results reveal that participants in the PSM group show a higher level of problem-solving confidence than the control group. It is hoped that the results of this research can inspire and encourage researchers and practitioners in a wider community to acknowledge the effectiveness of PSM, especially in the U.S.

This dissertation is dedicated to my family.

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INTRODUCTION

There is no shortage of methods to address complex problems. It is because each problem is unique and may require a unique approach. For example, Heppner (1978) indicates three different approaches regarding the problem-solving process: various learning approaches, traditional cognitive Gestalt approaches, and computer simulation and mathematics model approaches.

Even though each problem has unique elements, there are universal characteristics of a situation that enable us to label it as a problem. Sage (1992) indicates four characteristics that could define a problem:

1. There is a detectable gap between a present state and a desired state, and this creates a concern.
2. It may be difficult to bring about concordance between these two states.
3. The situation is important to some individual or group.
4. The situation is regarded as resolvable by an individual or a group, either directly or indirectly. (p. 232)

George (1994) argues that “a problem is not a real entity but a mental construct that is a representation of an unsatisfactory or threatening reality” (p. 241). Since a problem is a mental construct, it is important to have a shared understanding of the focusing problem when considering a group decision. Knowing what problem to work on could mitigate a possible confusion that might arise among individuals within a problem context. Each problematic situation is unique in its nature. Pidd and Woolley (1980) state that problems are abstracted from their embedded context, and they can only be properly understood in that specific context.

Characteristics of Problem Situations

Pidd (2009) distinguishes problematic situations in three significant categories: Puzzles, Problems, and Messes. A Puzzle is a problematic situation where a solution is clear to achieve. In other words, there is an answer that is definitely known to be correct, and there is a means to achieve the objective. It is a "set of circumstances where there is no ambiguity whatsoever once some thought has been given to what is happening or needs to be done. The issues that need to be faced are entirely clear, the range of options is completely known, and there exists a single correct solution to the puzzle" (Pidd, 2009, pp. 43-44). It may sound naïve to solve; however, a puzzle can be very mathematically complicated.

A Problem is a problematic situation where there is "no single answer that is definitely known to be correct…it depends on how you, or someone else, decide to construe it" (Pidd, 2009, p. 45). Within the relevant problem context, the desired solution to a problem can be achieved from different approaches. This is because "the solution approach used to address a problem may yield unique results from another, equally appropriate approach" (Hester & Adams, 2017, p. 27). Therefore, there may be an agreement about a core issue in a problem, but the desired solution may be achieved by numerous, equally valid means.

A Mess is a problematic situation where multiple stakeholders and interrelationships between issues exist. Real-world problematic situations are closer to the idea of a mess than a puzzle or a problem. A mess is complex because there is more than one stakeholder in the context (Hester & Adams, 2017). Pidd (2009) states that "a mess is a system of problems with multiple stakeholders who may hold quite different views of what is feasible and desirable" (p. 46). People address the problem with their cognitive resources, especially reflective thoughts (Smith, 1988). Based on an individual's cognitive capabilities, each stakeholder may have different perspectives about a problem that could potentially lead to a conflict. Mingers (2011) also elaborates that a messy problem has "a range of stakeholders with potentially conflicting values of interests, a lack of reliable data, disagreement about the nature of the 'problem' and yet the need for agreement and commitment from stakeholders" (p. 730). Another term that is used interchangeably to describe this type of problematic situation is *wicked problems*, coined by professor Horst Rittel of the University of California Architecture Department (Churchman, 1967).

The objective of a mess is unable to be explicitly addressed, possibly because of ill-structured problems, interrelationships among problems, and a multi-stakeholder environment. It should also be noted that there is no unique "right answer" in the messy problem (Ackermann, Alexander, Stephens, & Pincombe, 2020). A mess appears in a social problem where there are human factors, and no optimal solutions exist in the problem context (Rittel & Webber, 1973). However, there is a shared sense of what is not right. One of the goals of dealing with a messy problem is to develop a shared understanding of the situation (a group consensus) which provides a means of appreciating the different objectives and options among group members (Ackermann, 2011). Hester and Adams (2017) state that "a mess is better articulated not linguistically, as in the case of a problem, but graphically" (p.27).

Knowing the characteristics of a problematic situation helps us to understand which method(s) may be appropriate in addressing it. As Albert Einstein once said, "If I were given one hour to save the planet, I would spend 59 minutes defining the problem and one minute resolving it" (Spradlin, 2012). The ability to appropriately define a problem will provide a higher likelihood of a positive outcome in the problem-solving process.

Problem-Solving Methods

When there is a need to bridge the gap between the current and desired stage, people seek appropriate problem-solving methods. Linhart (1976) notes that the goal of the problem-solving process is the removal of the conflict and the finding of the desired object (as cited in Dostál, 2015). The roots of the theory of choice (i.e., problem-solving) stem from economics, statistics, and operations research (Simon et al., 1987). A majority of research in operations research focuses on the development of modeling techniques and finding an optimal solution to a problem. However, the selection of the methods should be "problem-oriented, not technique-oriented" (Ackoff, 1962, p. 2). In other words, the one universal problem-solving method never exists. Ackoff (1962) also argues that a successful problem-solving process needs to satisfy four conditions: the problem is properly formulated, the appropriate techniques are applied, a proper measure of effectiveness is used, and the results are implementable. As mentioned, there is no shortage of such methods. They vary from moving the problem forward to obtaining the optimal solution.

Hammond, Keeney, and Raiffa (1999) introduce the PrOACT (**Pr**oblem, **O**bjective, **A**lternative, **C**onsequences, **T**rade-off) approach as a practical decision-making approach. PrOACT is an example of a method that provides a step-by-step framework to help decision-makers make comprehensive decisions. Making the right decision leads to a high possibility of achieving the desired state. Heppner and Petersen (1982) also note that there are five practical stages in most problem-solving models: general orientation, problem definition, generation of alternatives, decision-making, and evaluation stages.

Another example of a step-by-step approach is introduced by Janis and Mann (1977) (as cited in Johnson & Johnson, 1982). The authors propose a seven-step ideal process which effective decision-makers should consider taking as follows:

1. They thoroughly canvass a wide range of possible courses of action.
2. They survey the full range of objectives to be fulfilled, and the values implied by the decision.
3. They carefully weigh whatever they know about the costs and risks of the negative consequences that could flow from each alternative.
4. They search intensively for new information relevant to further evaluation of the alternatives.
5. They correctly assimilate any new information of expert judgment to which they are exposed, even when the information of judgment does not support the course of action they initially prefer.
6. They reexamine the positive and negative consequences of all known alternatives, including those originally regarded as unacceptable, before making a final choice.
7. They make detailed provisions for implementing the chosen course of action, paying particular attention to contingency plans that might be required of various risks were to materialize. (Johnson & Johnson, 1982, p. 125)

At first glance, these problem-solving methods share similar attributes. They all have the characteristics of structuring a problem *before* making a decision (i.e., solving a problem). The only considerable difference is the notion of risk assessment in the latter method, which is addressed in Horlick-Jones, Rosenhead, Georgiou, Ravetzd, and Löfstedte (2001). These step-by-step approaches are more suitable for a simple rather than a complex problem. Thus, other problem-solving methods are discussed to better deal with a more complex problem.

Complexity is always critical in a problem-solving process. As Jackson and Keys (1984) state, “A simple system will be perceived to consist of a small number of elements, and the interactions between these elements will be few, or at least regular. A complex system will, on the other hand, be seen as being composed of a large number of elements, and these will be highly interrelated” (p. 475). These aspects of complexity can be divided into two types: technical complexity and human/social complexity – as hard and soft perspectives, respectively (Daellenbach, 2001). Both of these aspects have distinctive characteristics. The ability to distinguish them is essential with respect to a selection of tools or methods to solve a given problem. This is because the failure to select appropriate methods for a problematic situation could lead to a chance of committing an error.

Operations Research

Operations Research (OR) has been executed as one of the primary problem-solving methods for decades. The method was invented as the application of the scientific approach to modern warfare (Hansen, 1989). Ackoff (1962) states that “the purpose of operational research is to improve operations” (p. 10). A traditional OR approach usually appears in a quantitative environment (Daellenbach, 2001).

Operations Research (Operational Research for some) has been routinely employed across industry and academia for over a half-century as a primary problem-solving method. This methodology was formulated in England during World War II. Heyer (2004) provides some historical information on the evolution of the methodology:

> OR rose to prominence during World War II largely due to the British military. In the days leading up to World War II, British

> military management assembled a group of scientists to apply a scientific approach to military operations to determine the most advantageous ways to deploy their massive materiel and manpower. Soon after, the United States military began engaging in OR using specialists from fields such as chemistry, mathematics, and engineering to create management techniques for allocating scarce resources and to achieve both military and industrial goals (Carter & Price, 2001). In the 1950s various academic societies were born in both Britain (who today prefer the term operational research) and the United States (who prefer the term management science) for operations researchers (those who practice OR) to promote, develop and exchange ideas in the field. These professional societies remain active today and the field of OR has grown even larger and more diverse. (p.1)

Traditional OR (or management science or decision science to some) involves the use of quantitative approaches to aid in decision making. It helps an analyst determine how to design, operate, and make a decision on a system scientifically under conditions requiring the allocation of scarce resources. This approach involves the use of methods such as spreadsheets, computer simulations, statistical analysis, or optimization techniques (Daellenbach, 2001).

The applications of traditional OR methods are usually found in product design, quality design, flow design, scheduling, and planning or services industries. Their analytic methods provide solutions to many organizations, including “financial institutions, extractive and manufacturing industry, airlines and rail companies, and many more in our society” (Rosenhead & Mingers, 2001, p. 9). The applications and contributions of traditional OR methods to real-world problems are discussed extensively in the literature (Al-Thani, Ahmed, & Haouari, 2016; Barnhart, Belobaba, & Odoni, 2003; Steenken, Voß, & Stahlbock, 2004). The nature of these applications is one of the reasons that traditional OR is widely executed. It is because a traditional OR method involves the use of a quantitative approach as elaborated earlier. Therefore, it is not complicated to conclude that the approach generates a better result – by comparing numbers/results of before and after the intervention. In other words, there is a succinct measurement of the outcome of a traditional OR intervention.

There are some criticisms regarding the inability of traditional OR methods to comprehensively address realistic problems (Ackoff, 1979; Mingers, 2011). Specifically, those involve human elements, as outlined above. Researchers have been trying to propose an alternative, complementary approach to tackling a problematic situation due to the complexity where traditional OR might not be effectively applied. Rosenhead and Mingers (2001) introduce the applications of a family of methods, Problem Structuring Methods (PSM), to structure problems and find ways to move them forward rather than trying to find a single optimal solution. PSM started to become visible, within OR societies, in the mid-1960s as soft OR methods (Mingers & Rosenhead, 2004). Kotiadis and Mingers (2006) argue that soft OR methods have evolved within OR "to better deal with messy, wicked and complex problems that are not amenable to the traditional, largely quantitative, OR techniques" (p. 856). Some of the objectives of soft OR interventions are to facilitate an exchange of views between participants, to achieve a better understanding of an individual's point of view, to generate an agenda of actions for further discussions (Ormerod, 2018). Eden and Ackermann (2006) also state that PSM interventions seek to facilitate agreements to act and move a problematic situation forward.

Both traditional OR and soft OR have their unique characteristics and can be beneficial in different situations. Heyer (2004) states that traditional OR can be considered as hard OR, while PSM can be referred to as soft OR. Both terms appear interchangeably in the literature. Thus, they will be called interchangeably in this document as well. A hard approach (traditional OR) "refers to the use of mathematical and quantitative techniques as opposed to softer research that employs predominantly qualitative techniques" (Heyer, 2004, p. 2). In other words, a hard approach is helpful in a ‘cost-benefit analysis’ environment while the soft approach is more useful in a “cause-effect analysis” (Van der Hoff & Harding, 2017) environment.

The characteristics of a problem will define an appropriate tool(s) to solve that problem. Ackoff (1962) believes that a good selection of problem-solving methods should be problem-oriented. The following section discusses the possible linkages between a problem’s characteristics and potential methods.

Characteristics of Hard OR Problems

Daellenbach (2001) identifies five characteristics of a situation where hard OR approach may be appropriate:

1. The problem(s) in a situation is clearly defined. This means the objectives have been clarified, and there is a criterion to determine means to reach the goals. Also, the possible alternatives are specified by the known decision-makers. All input, data, constraints are available.
2. The problem(s) in a situation is relatively well structured. It means the relationships and interactions among elements/variables are or can be known. They can be expressed in quantitative form, and the computational effort is feasible to determine the optimum solution.
3. The problem(s) in a situation can be isolated from the wider system of interest, meaning that the situation is hardly affected by other systems.
4. The problem(s) in a situation is in a technical form and mostly free from human aspects
5. The problem(s) in a situation has evident decision-makers, and they can enforce the implementation of the solution.

Checkland (1999) states that a hard OR problem can be described as a situation where "there is a desired state, S_1, and a present state, S_0, and alternative ways of getting from S_0 to S_1. 'Problem-solving,' according to this view, consists of defining S_1 and S_0 and selecting the best means of reducing the difference between them" (p. 138). It is similar to a puzzle discussed in Pidd (2009). Also, a hard OR problem involves "systematically-ordered thinking concerned with means-definition in a well-structured problem in which desirable ends can be stated" (Rosenhead & Mingers, 2001, p. 7). Such problems may exhibit a high level of complexity, requiring significant technical expertise to address. Problems with these characteristics tend to be solved by hard OR methods. Ackoff (1979) characterizes a hard OR approach as "mathematically sophisticated but contextually naïve" (p. 94). As stated earlier, these approaches mostly involve the use of mathematics – in the form of spreadsheets, computer simulations, statistical analysis, scheduling, and optimization techniques. Therefore, the analyst is usually an expert in the problem-solving process (Sørensen & Vidal, 2008). They have been successful in dealing with highly technical problems. Due to their nature (optimal-solution-seeking), most people have used these techniques to address problems.

However, issues arise when analysts try to utilize hard OR methods within a highly human-oriented type of problem (Checkland, 1983; Heyer, 2004). Funtowicz and Ravetz (2003) argue that modeling exercises (hard OR) are inclined to committing an error when the gap between the available data with a manageable model and the real policy situation cannot be bridged. In other words, the desired state will never be reached with a good tool in the wrong problem context.

Mingers (2008) states that the limitations of traditional OR (hard OR) started to become evident during the 1960s and 1970s when human and social aspects of problems became more noticeable. As elaborated earlier, this class of problems called a mess (Pidd, 2009) or a wicked problem (Rittel & Webber, 1973). It holds "many alternative types and levels of explanation of the phenomena of concern, and the type of explanation selected determines the nature of the solution" (Rosenhead & Mingers, 2001, p. 5). Hester and Adams (2014) argue that "the immediate result of a wicked problem is the questionable ability of traditional approaches based upon a single technical perspective to be successful" (p.26). Checkland (2001) adds that the rich complexity of the world sometimes could not be modeled or optimized. Ackoff (1981) concludes that a problem can be solved, but a mess can only be managed.

In addition, Hopp and Spearman (2000) argue that "much of the scheduling research suffers from type III error: solving the wrong problem" (p. 497). The authors also indicate that most real-world problems violate the assumptions which need to be made in a hard OR approach (e.g., scheduling theory). The notion of the Type III error will be discussed in the following section. At this point, making quick and inadequate assumptions regarding a complex problem or mess can lead to committing a Type III error – solving the wrong problem correctly (Adams & Hester, 2012). Therefore, there is a need to explore alternative paradigms than a traditional (hard) OR (Hansen, 1989).

Characteristics of Soft OR Problems

First of all, it should be noted that the word "soft" does not mean that the analysis will be conducted carelessly (Checkland, 2000; Eden & Ackermann, 2006). Social problems can be defined as ill-structured problems because of the nature of problematic situations. Thomas and Gunden (2010) provide some characteristics of these problems:

- Having conflicting goals
- Exhibiting complex patterns of relationships with other problems
- Consisting of interacting subproblems

- Requiring the application of multiple disciplines in crafting and implementing solutions
- Having no single best solution for their resolution
- Having multiple criteria for evaluating solutions
- Having solution conditions that are not well specified (p. 153)

These characteristics are similar to a mess, which is discussed in Pidd (2009). This type of problem is not objective oriented, and it is doubtful that traditional OR methods can efficiently solve it (Rosenhead & Mingers, 2001). Jackson (2000) confirms that the assumptions in hard OR methods "are usually too simplistic to capture the real-world complexity of the situation" (p.129). People understand and interpret a problematic situation differently and often do not realize it (Mingers, 2011). Soft OR approaches were introduced in the OR community to address those limitations. These emerging approaches focus on structuring the problems rather than solving them (Rosenhead & Mingers, 2001). Eden and Ackermann (2006) argue that the methods do not only structure the problem of interest; they also seek to facilitate agreements to act.

Soft OR methods can manage problems that involve a heavy dose of human elements, and often a variety of stakeholders with different worldviews (Rosenhead & Mingers, 2001). An agreement on the objective may not be found in this type of problem, often due to the diversity of stakeholders' perspectives. Given that the objective itself may not be agreed-upon, it may be meaningless to talk about optimization or any computational (i.e., hard OR) approaches (Daellenbach, 2001). Soft systems thinking can be beneficial in structuring our thoughts, learning about these problems, and obtaining a better understanding of the problem to move the situation forward, rather than optimally solving it. A Soft OR method has the ability to address most of the issues mentioned in this section. Researchers support that a soft OR approach can be a complementary alternative to hard OR (Cook, 2011; Franco & Lord, 2011; Lewis & Elmualim, 2011; Mingers, 2001; Mingers & Brocklesby, 1997; Munro & Mingers, 2002; Pollack, 2009; Sibbesen & Leleur, 2006). Table 1 illustrates the characteristics of both hard and soft perspectives. The five attributes indicate the different views from the two viewpoints.

Table 1. Attributes of Hard and Soft Systems Perspective (Hester & Adams, 2014)

Attribute	Hard perspective	Soft perspective
Worldview	A real-world exists external to the analyst	Perspectives of reality are dynamic & shifting
Data	Factual, truthful and unambiguous data can be gathered, observed, collected, and objectively analyzed	Data is subjective in collection and interpretation – analysis strives for transparency
System	The system in focus is unaffected by either the analysis or the analyst	The system in focus is affected by both the analysis as well as the analyst
Value	The analysis can be conducted free of value judgments	The analysis and interpretation of analysis is value-laden
Boundaries	The system in focus can be bounded, and the analysis can be controlled – this is both possible and desirable	Bounding off the system in focus is problematic, control of the analysis is questionable – emergence is dominant

As shown in Table 1, a hard perspective primarily focuses on how to solve the problem more than how to gain a better understanding of the problem. Checkland (2006) also believes that a hard approach focuses “on carefully defining goals or objectives and then creating a system to meet those objectives, both of which are taken as given rather than examined” (p. 769). A problem often occurs in a situation where there may be an agreement about the core issue, but there may be a range of means/approaches in working towards a solution. It only requires the correct implementation to obtain the desired result. A hard OR method is appropriate for this type of problem because it tends to find the 'best' solution to the problem (Rosenhead & Mingers, 2001).

On the other hand, a soft perspective focuses more on context-oriented aspects in the problematic situation rather than on how to solve the problem objectively. As mentioned earlier, this type of problem often involves in the environment where there are ambiguities about objectives and uncertainty about the outcomes. To deal with this type of problem, Rosenhead and Mingers (2001) argue that there should not be a "specification of optimal means" (p.5). In other words, there is no 'best' solution to such problems. In conclusion, it is fair to conclude that a hard OR methods focus on the visible end products, while soft OR methods support the involvement of individuals' perspectives in providing a learning process in a problematic situation (Sørensen & Vidal, 2008).

Error in Problem-Solving

Each problem is unique and requires a distinctive approach(es). As Kaplan (1973) states that "give a small boy a hammer, and he will find that everything he encounters needs pounding (p.28)." It is fair to say that "when there is a hammer, it does not mean that every problem turns into a nail." Kaplan (1973) calls this phenomenon *the law of the instrument.* It is where people tend to formulate problems in a way that they could expect outcomes from their familiar tools. This is prone to an error, as discussed in Ackoff (1981), because some problems can be solved, and some can only be managed. In other words, there is no universal problem-solving method. To avoid committing an error, the problem needs to be well structured before being solved.

To structure a problem is critical because an individual has the potential to commit a Type III error if the right problem is not well-defined (Adams & Hester, 2012). As Mitrofff and Betz (1972) state that a Type III error is "the error of the third kind, i.e., that of solving the 'wrong' decision problem when one should have solved the ‘right’ problem, is of fundamental importance to management science” (p. 11). It is an error where an individual ends up solving the wrong problem precisely (Adams & Hester, 2012). Hammond et al. (1999) elaborate on the situation when someone could potentially commit a Type III error:

> Too often, people give short shrift to problem situation… In their impatience to get on with things, they plunge into the other elements of decision making without correctly formulating the problem first. Though they may feel like they’re making progress in solving their problem, to us they seem like travelers barreling along a highway, satisfied to be going 60 miles an hour – without realizing they’re going the wrong way. (p.26)

Blanchard (2004) indicates the importance of defining the correct problem stating that it is “the most difficult part of the process, particularly if one is in a rush to ‘get going’” (p.48). This rush to get going could lead to downstream issues – a wasted effort that is trying to solve a wrong problem formulation (i.e., Type III error). Thomas and Gunden (2010) agree that rushing to a solution in any problematic situation without investing sufficient effort to define the right problem could lead to a Type III error. Yadav and Korukonda (1985) state that the confusion between causes and symptoms is a major source of Type III error. The authors argue that an “inadequate analysis of symptoms at the design stage could sometimes lead to a wrong built-in solution” (Yadav & Korukonda, 1985, p. 56). The inadequate attention to human and organizational issues is one of the main contributors to an error in a problem-solving process (McKay & Marshall, 2005).

Type III errors are more general than Type I (errors involving the rejection of the null hypothesis when it is true) and Type II (errors where one accepts the null hypothesis when it is false) errors. Rasch (2012) notes that Type III errors are not typically subjected to hypothesis testing, although Mosteller’s (1948) original formulation of the Type III error described it in terms of hypothesis testing. Boal and Meckler (2010) state that Type III error "is the result of incorrectly seeing what needs to be done, leaving the 'true' problem outside of the attention of the decision-makers" (p. 10). Thus, it requires efforts to formulate the right problem before solving it. It is worth noting, however, that formulating a problem from a predefined solution or familiar methodologies may also contribute to a Type III error (Yadav & Korukonda, 1985). There is a high possibility of wasting scarce resources on irrelevant problem-solving efforts if an individual ignores or denies the existence of a Type III error. As Pidd (2009) elaborates his own experience with the potential to commit a Type III error:

> Much of my own technical expertise is in discrete computer simulation … whenever I am asked about aspects of certain dynamics, I envisage the system in terms that make it easy to simulate. Needless to say, this applies a set of blinkers that enables me, like a racehorse, to make rapid progress, but I do so at risk of running in the wrong direction or even wrong race. (p.53)

As mentioned earlier, people tend to utilize the tool and method based on their familiarity. It is not entirely correct since there is no such tool that can effectively solve every problem. In a problem-solving process, the desired state will never be reached with an excellent tool in a wrong/unaligned problem. All the resources and efforts can be wasted by solving the wrong problem – committing a Type III error.

There are pieces of evidence where researchers connect the limitations of a hard OR approach with a notion of Type III error. Hopp and Spearman (2000) indicate that "much of the scheduling research suffers from Type III error" (p. 497). The authors also specify that most real-world problems – based highly on social aspects (human, preference, and other subjective elements) – violate the assumptions which need to be made in scheduling theory (i.e., hard approach). In other words, making quick and inadequate assumptions regarding a complex problem can lead to committing a Type III error. Also, as stated earlier, Funtowicz and Ravetz

(2003) argue that modeling exercises in hard OR are inclined to committing a Type III error when the gap between the available data with a manageable model and the real policy situation cannot be bridged.

Example of Committing a Type III error

Collins, Shull, and Thaviphoke (2019) provide a simple case for a Type III error. The authors demonstrate the dangers of jumping into the problem with a common tool, which leads to a false conclusion. Another example of committing a Type III error is the following:

Suppose that you own a small delivery company and keep getting complaints about late deliveries. Because of this issue, you want to minimize overall delivery time – to have merchandise delivered on time and to satisfy customers. One of the solutions that may naturally arise in your mind is whether your delivery routes and vehicle assignments are optimal. This is a classic hard OR problem – the vehicle routing problem. Optimization methods (a hard OR approach) as a means of solving this problem would usually be the first solution approach that comes to mind. It is because people just want the ‘answer’ for the problem. As elaborated earlier, rushing to the answer may not be the best approach. There should be an effort to formulate the right problem before solving it.

The right problem might not be with the delivery routes at all. There are many factors associated with this problematic situation. One of the factors that could cause this problem could be the driver. This driver may not have good knowledge in the delivery route/area; he might not have a good driving skill; he might be unhappy with his salary, might not be happy with this work schedule, and so on. Suppose that you selected to spend significant resources optimizing your delivery routes and vehicle assignments, while the actual problem (unhappy drivers) was not the one you solved. The problem will stay even though the best delivery route is used. This is a prime example of a Type III error (solving the wrong problem precisely). The use of a soft OR lens may have revealed that optimizing delivery routes was not the root problem after all.

The best delivery route can be obtained by the use of an optimization method (a hard OR approach). If finding the best delivery route is the actual problem, you have it solved correctly. However, in this specific example, you solved the wrong problem correctly. The problem is not with the delivery route at all, but rather with the driver. You will not be able to solve the actual problem with the product of this problem-solving process – the optimal delivery route in this case.

On the other hand, if an appropriate analysis (a soft OR approach) was conducted at the outset, and the result of the analysis indicated that the problem was a delivery route, you could get your desired answer from the optimization process (a hard OR approach). This is one of the examples to show that two approaches can complement each other when applied together in a problem-solving process. Mingers and Brocklesby (1997) discuss the benefit of applying both methods in a problem-solving intervention.

Motivation

Solving the wrong problem precisely – Type III error – is one of the most important errors associated with a problem-solving process (Mitroff & Featheringham, 1974). It is significant to the extent that the error could cause a considerable amount of scarce resources for a problem-solving process that does not produce the desired outcome. Not only that the desired outcome is not reached, but there is also a chance to create additional problems. Mitroff and Featheringham (1974) state that Type III error "may be a more fundamental decision-making error than the usual statistical errors" (p. 393). Yadav and Korukonda (1985) argue that the beginning of committing a Type III error initiates at the perception of the problem. In other words, the possibility of committing a Type III error usually occurs in the process when one formulates the (wrong) problem (Hester & Adams, 2017). Problem formulation is one of the crucial stages in a problem-solving process. Kilmann and Mitroff (1979) conceptualize five stages of the problem-solving process, as shown below:

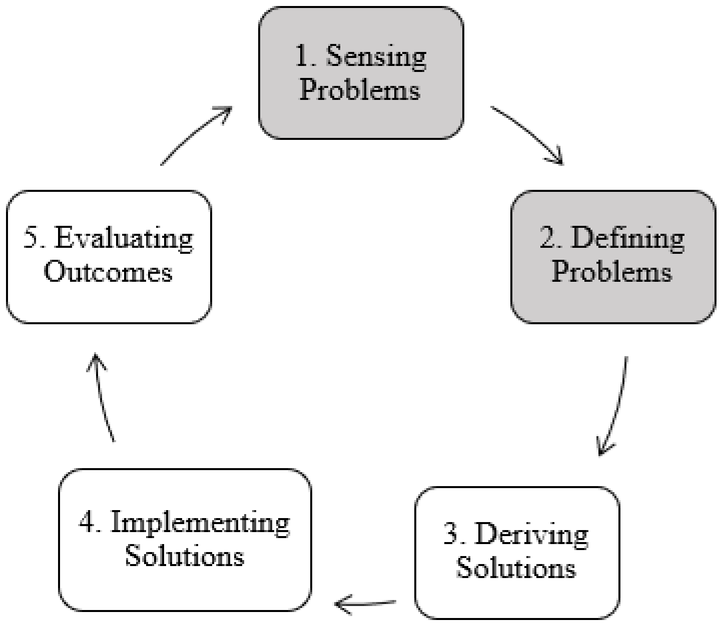

Figure 1. The Intervention Process

Figure 1 shows five stages of a problem-solving process where the shaded stages (one and two) can be considered the problem formulation stages. If an individual enters the process at stage three (deriving solutions), there is a high possibility of committing a Type III error (Kilmann & Mitroff, 1979; Yadav & Korukonda, 1985). Awareness of the existence of Type III errors should ensure an effective problem-solving process and reduce the chance to raise additional problems.

Dealing with a mess is prone to committing an error. Volkema (1983) believes that one of the ways to mitigate a chance to commit a Type III error is to allocate more time and energy to the problem formulation process. However, within a problem-solving process, there is very little attention that "has been given to problem finding, problem formulating, or problem creating" (Kilmann & Mitroff, 1979, p. 27). A dialectic, cause-effect, approach is suggested to reach a higher level of understanding in the process of problem formulation (Yadav & Korukonda, 1985). According to their characteristics, it is fair to state that most (if not all) of the social problems can be considered a mess. Within a mess, a comprehensive problem representation which shares some level of problem understandings could generate a more efficient problem formulation. Mingers (2011) argues that the generation of a degree of agreement – a group consensus – can be one of the ways to deal with a messy problem.

As noted earlier, soft OR approaches became visible in OR community to help structure the problems. Rosenhead and Mingers (2001) introduce the term problem structuring methods (PSM), which have a more qualitative way of analysis, softer, than the traditional hard OR approach. It is acceptable to infer that soft OR methods and PSM share the same theoretical paradigm. The issue with the vagueness in terminology will be discussed later. As mentioned earlier, the fundamental objectives of these methods are to explore the problematic situation and generate a shared understanding, which could lead to an agreement among members in a group decision (i.e., a mess) (McKay & Marshall, 2005). PSM also has the potentials to help manage a mess, as discussed in Ackoff (1981). There are some challenges and criticisms of the application of PSM, which will be elaborated later in this document.

Purpose and Relevance of Research

This research effort is motivated by the literature where there is a need to investigate the usefulness of a problem-structuring process in a problem solving intervention within messy problems.

Outline of Disseration

The literature review provides an overview of Problem Structuring Methods (PSM) including some of the expectations and criticisms. In addition, Strategic Options Development and

Analysis (SODA) process is reviewed as one of the widely used PSM. According to the current challenges, the research question is identified. The experimental design is then discussed to address the current research question. After that, the results of the experiment are revealed. In conclusion, the discussion, implications, limitations of this study, and future research are provided.

CHAPTER 2

LITERATURE REVIEW

Problem Structuring Methods (PSM)

Given the complexity in problematic situations these days, a Problem Structuring Method (PSM) can be one of the valuable tools in the modern-day problem intervention (Jackson, 2006). The origin of PSM arose in the mid-1960s and became more evident in the late 1980s (Rosenhead, 2006). The terminology is diverse in the literature – soft OR (Heyer, 2004; Seagriff & Lord, 2011), problem finding (Pounds, 1969), problem formulation (Lyles, 1981; Schwenk & Thomas, 1983), problem definition (Kilmann & Mitroff, 1979; Smith, 1989), and exploration approach (Pidd & Woolley, 1980). They all share the same theoretical foundation, which is to structure/formulate the right problem within a problematic situation.

Shaw, Franco, and Westcombe (2006) define PSM as "a collection of participatory modeling approaches that aim to support the diverse collection of actors in addressing a problematic situation of shared concern" (p. 757). Horlick-Jones et al. (2001) also describe PSM as "a set of tools designed to assist management groups to agree the nature and boundaries of problems which they must tackle, and to secure shared commitment to action" (p. 144). These methods share similar focusing areas: problems in organizations and groups, the significance of reaching agreements to act as opposed to single optimal solution, and a respect for multiple perspectives (Eden & Ackermann, 2006). A more straightforward definition from Collins et al. (2019) is "the mental tool that helps us understand the problem" (p. 76).

As stated earlier, PSM was developed because the limitations of traditional OR started to arise. Researchers (Ackoff, 1962; Ackoff, 1979; Checkland, 1983; Churchman, 1967) argue that the assumptions in traditional OR – relevant factors, constraints, and the objective functions – are made way in advance. Also, formulating a problem from a predefined solution (i.e., assumptions) or methodologies may contribute to an error (Yadav & Korukonda, 1985). From the beginning, the emphasis of traditional OR is on "modeling the factors and relationships in a decision situation mathematically and then using computer power to review the predicted consequences of alternative choices. Mostly the tools and techniques within this approach aim to find the 'best' solution" (Rosenhead & Mingers, 2001, p. 1).

It is doubtful that the foundation of traditional OR will be perfectly applied in the full rigor of the connected and turbulent world. The limitations of traditional OR became more visible when the complexity of human and social aspects of problems became more noticeable (Mingers, 2008). Under a traditional OR lens, it is believed that there is a "possibility of a single uncontested representation of the problem situation under consideration" (Rosenhead, 2006). However, as mentioned, the rich complexity of the world sometimes cannot be modeled, let alone optimized. One of the most important objectives of PSM intervention is to elicit relevant information and reflect it in a structured form (Rosenhead, 1996). Within a mess, PSM has the potentials to capture and structure the problematic situation since they "share an emphasis on the use of visual and qualitative representations of an issue" (Belton & Stewart, 2010, p. 10).

PSM generates shared understandings in a group of decision-makers (Cronin, Midgley, & Jackson, 2014; Midgley et al., 2013). The methods are appropriate to address the situation where there are different views from stakeholders and possibly conflicting perceptions about the focusing problem (Den Hengst, De Vreede, & Maghnouji, 2007). Since every problem is unique and people have different perceptions of a problem, a PSM is commonly applied in a creative setting that takes account of local circumstances – context-oriented approach. Woolley and Pidd (1981) highlight that PSM intervention is a “process of arriving at a sufficient understanding of the components of a particular problem to proceed to some sort of useful operational research work” (p.198).

In most PSM interventions, an analyst (so-called facilitator) operates as an unbiased moderator who facilitates the participants to express their thoughts and move them toward an agreed course of action (Den Hengst et al., 2007). Rosenhead and Mingers (2001) also explain that the process “is the workshop that the model or models representing cause and effect are built up, integrated, amended, transformed through the collaboration of the modeller and the group” (p.13). Given the importance of the role, there is a need for a well-rounded facilitator in a successful PSM intervention (Pidd, 2009; Rosenhead & Mingers, 2001). A good facilitator tends to promote a participative and structured conversation, to encourage the participants to express their views of the problem, and to help with the synthesis of focusing information (Marttunen, Lienert, & Belton, 2017). A good facilitator is sensitive to the dynamics that take place among the participants during the process. In addition, a facilitator also needs to be aware of these notions: transparency in modeling, powerful and easy to understand group-based model, facilitation techniques to deal with group dynamics, model quality, and efficiency of the process (Ackermann, 1996; Hengst & Vreede, 2004).

Over the past few decades, some methods have become particularly well known under the PSM umbrella. These methods are the Soft Systems Methodology (SSM) (Checkland, 2000; Patel, 1995; Winter, 2006), Strategic Choice Approach (SCA) (Child, 1997; Friend & Hickling, 2005), Strategic Options Development and Analysis (SODA) (Eden & Ackermann, 2001, 2006), Cognitive mapping (Eden, 2004; Eden, Ackermann, & Cropper, 1992), and other Problem Structuring Methods (Checkland, 2001; Ritchey, 2006; Rosenhead & Mingers, 2001). One of the reasons that PSM emerged in OR is because people tend to jump to the conclusion without spending some effort to find out the actual problem (Collins et al., 2019; Thomas & Gunden, 2010), which could lead to an error in a problem-solving intervention.

Under the PSM umbrella, these methods share some similarities with the underlying aspects. They "share an emphasis on the use of visual and qualitative representations of an issue" (Belton & Stewart, 2010, p. 10). A PSM helps determine how to design, operate, and make a decision on a system under consideration. Eden and Ackermann (2006) elaborate on the similarities as follows:

1. Use of a model as a transitional object
    a. Models are populated with data that are specific to the problem
    b. Models are not intended to lead to optimal solutions; instead, they facilitate negotiations and discussions that could lead to the agreements
    c. Models drive the process of negotiation towards agreement through discussion and the development of a common understanding
2. Increasing the overall productivity of group processes
    a. Models tend to include members' perspectives as many as possible to construct better agreements within the organization. This increases the possibility to avoid committing a Type III error
3. Attention to the facilitation of effective group processes
    a. Models tend to include power and political aspects within organizational settings. These two aspects can make a big impact on the system of interest
4. Appreciation of the significance of facilitation skills to enable effective model building
    a. The analyst takes a facilitator role, rather than a solver
    b. The ability to manage both process and content skills

c. Having sufficient flexibility and knowledge to operate the methods throughout the process. In other words, to facilitate the group's need rather than follow linear steps

These similarities indicate the importance of the intellectual processes where a group of people and a facilitator use models to help with "sense-making in the search for action" (Checkland, 2006, p. 770). Daellenbach (2001) also identifies five characteristics of a situation where PSM may be appropriate:

1. The problematic situation does not need to be solved (does not seek the ultimate solution), rather structure a situation and move forward from the current situation.
2. The stakeholders in the situation have different worldviews. There is a need for a shared perspective among the stakeholders before making a decision.
3. The situation needs more of the 'What' questions more than the 'How' questions. This 'What' type of question tends to shape stakeholders' multiple worldviews into a shared perspective among them. For example, 'what is the issue?' 'what are the objectives?' 'what changes do we have to make to be able to reach the objective?' and so on.
4. The situation is one where insightful aspects are generated through debate and negotiation among stakeholders (stakeholders' interrelationships).
5. The situation needs a facilitator, not a solver.

Combination of Applications

As discussed earlier, it is evident that there are some differences and similarities in both hard (traditional OR) and soft (PSM) approaches. However, the hard-soft divide is "equally misguided" (Rosenhead, 1996, p. 128). Both methods can contribute to an effective problem-solving process. Each problem has unique characteristics and requires a different method – one cannot perform the tasks of another (Robinson, 2007). Some problems require an approach that can move the situation forward, and some need a single/globally optimal solution. Checkland (2006) confirms, in a complementary to hard approach, that PSM "will help to create a new and richer conventional wisdom in the management field" (p. 770). In a total problem-solving intervention, PSM has also been considered as a front-end approach of the process (Mingers & Brocklesby, 1997; Rosenhead, 1996; Rosenhead & Mingers, 2001; Smith, 1989). It is because these methods focus on relevant information, multiple views, and interpretations of the system of interest (i.e., system contexts) before making informed decisions (Bell, 2012). PSM has the potentials to work in concert with hard OR approaches and, together, make a problem-solving process more efficient.

Rosenhead (2006) also confirms the relationship between the two sides, stating, "they reinforce each other" (p.763). As stated earlier, hard OR methods have the potential to commit a Type III error, while PSM has the potential to help prevent it. It is argued by Smith (1989) who claims that PSM may be "the best defense against Type III error" (p. 966). Both hard and soft OR methods are not binary (all or nothing). Instead, there is a midpoint where these two approaches can work together effectively (Lewis & Elmualim, 2011; Mingers, 2001; Mingers & Brocklesby, 1997; Munro & Mingers, 2002; Pollack, 2009). Marttunen et al. (2017) agree that combining methods generates a richer view of a problematic situation before making an informed decision. The notion of applying multiple methods in the same problem-solving intervention is another area of research, which is discussed in e Silva Filho, Fontana, and Morais (2014); Marttunen et al. (2017); Mingers (2000); Mingers and Brocklesby (1997). The multimethodology is not the core of this current research. This study will solely focus on the effectiveness of PSM.

Expected Outcomes of PSM

Mingers and Rosenhead (2004) indicate five different areas that PSM has been applied: General organization applications, information systems, technology and resources planning, health service, and general research. Public policymaking is one of the most significant areas of PSM application (Rosenhead, 1996). The success of PSM practical cases can be found in Cronin et al. (2014); McKay and Marshall (2005); Mingers and Rosenhead (2004); Munro and Mingers (2002); Pidd and Woolley (1980); Rosenhead and Mingers (2001).

The fundamental concept of PSM started from the idea that "problems are malleable and can be moulded into a variety of shapes and forms" (Pidd, 2009, p. 50). Mingers and Rosenhead (2004) explain that PSM offers a means of "representing the situation – a model or models – that will enable participants to clarify their predicament, converge on a potentially actionable mutual problem or issue within it, and agree commitments that will at least partially resolve it" (p.531). As discussed earlier, models in PSM are not intended to lead to optimal solutions. They facilitate negotiations and agreements. Therefore, it is acceptable to say that a level of shared understanding can be expected from PSM intervention.

One of the purposes of PSM intervention is to construct the right problem that could be manageable among individuals within a problem context. A learning process, within a PSM intervention, provides an opportunity to formulate the right problem. Each individual will have an opportunity to learn about the focusing problem from multiple perspectives. The learning process (i.e., to structure the right problem) may take time, yet it is better to solve the right problem than to solve the problem right (Curtis, Dortmans, & Ciuk, 2006). Hester, Collins, Ezell, and Horst (2016) confirm that "incorrect identification of our problem increases the likelihood of us committing a Type III error" (p.4). As mentioned earlier, one of the most promising outcomes of PSM is to mitigate the chance of committing a Type III error (Smith, 1989).

Mingers and Taylor (1992) conduct a survey of 294 samples and find out that people expect the development of problem understanding from a PSM. The results indicate 13 outcomes within three categories, as shown in Table 2 below:

Table 2. Main Benefits of a PSM, adapted from Mingers and Taylor (1992)

Categories	Reported main benefits
Managing the intervention	Provides a structure/framework for the study
	Gives a complete/wide-ranging/holistic view
	Good tool for communication
	Improves the speed of study
In thinking process	Provides clarity of thoughts/structured thinking
	Promotes shared thinking/gets people together
	Frees you from the current situation
	Forces explicitness
	Promotes creative and stimulating thinking
Concerning the problem content system	Structures situations which are complex/messy/have much information
	Generates an understanding of other people's perceptions and perspectives
	Focus attention on issues and organization culture
	Does not make assumptions about the situation

Table 2 shows all 13 main benefits of a PSM that were collected from the survey. According to the results, the most important benefits are "provides clarity of thoughts/structured thinking" and "provides a structure/framework for study" (Mingers & Taylor, 1992, p. 327).

Rouwette (2003) identifies five main expected outcomes of a PSM intervention: mental model refinement, fostering quality of communication, creation of consensus, implementation of system changes, and system improvement. Franco (2007) also identifies some of the expected outcomes from the application of PSM, which are: model and problem structure, accommodations of multiple positions, a shift in power relations, increased understanding and learning, ownership of problem structure, and consequence of planned actions, and partial commitments. One of the most apparent outcomes of PSM interventions is the structured model, which acts as a ‘negotiative device’ (Eden, 1988; Thaviphoke & Collins, 2019a).

Applying PSM as a negotiative device provides an increase of problem understanding during an intervention (Franco, 2007). Cronin et al. (2014) implement a PSM in a risk communication context and report five outcomes from the intervention: an increased mutual understanding, reduced conflict, identified common ground, trust-building, and supported the emergence of the policy. McKay and Marshall (2005) report a shared understanding among people in a group as an outcome of PSM intervention. Also, the outcome provides the means for better communications among members in a group. Table 3 indicates eight different expected outcomes of PSM interventions. Even though there are some indications of the effectiveness of the methods, these reports are self-reports.

Table 3. Expected Outcomes from PSM interventions.

Some reported expected outcomes	See for examples
1. Increased mutual understanding, 2. A clarity of thoughts (transparency), 3. Increased understanding of the focusing problem, 4. A formulation of the "right" problem, 5. A representation of the focusing problem, 6. Enhanced the communication quality in a group, 7. Organizational learning, 8. Generations of agreements among stakeholders	Connell (2001); Cronin et al. (2014); Curtis et al. (2006); Eden and Ackermann (2006); Franco (2007); McKay and Marshall (2005); Mingers (2011); Mingers and Rosenhead (2004); Mingers and Taylor (1992); Nakagawa, Shiroyama, Kuroda, and Suzuki (2010); Rouwette (2003)

On the other hand, there are some reports on the negative outcome of the PSM interventions as well. The results from Mingers and Taylor (1992) also indicate time-consuming and lack of confidence as the criticisms regarding a PSM intervention. The time-consuming criticism comes from the respondents who had experience with the method, while the lack of confidence is from the respondents who had no experience with the method. These two criticisms are somewhat expected, which will be elaborated next section. Table 4 indicates some of the criticisms in the field.

Table 4. Reported Criticisms of PSM Interventions

Some reported expected outcomes	See for examples
1. Time-consuming,	Collins et al. (2019); Cronin et al. (2014);
2. Lack of confidence,	Jenkins (1998); Marttunen et al. (2017);
3. Hard to identify clear benefits,	Midgley et al. (2013); Mingers (2011);
4. Need skillful facilitators,	Mingers and Taylor (1992); Rosenhead and
5. High-level of participants attentions	Mingers (2001); White (2006)

Some Challenges

The challenges in the PSM community are well documented in the literature (Ackermann, Franco, Rouwette, & White, 2014; Checkland, 2006; Collins et al., 2019; Eden & Ackermann, 2006; Keys, 2006; Mingers, 2011; Mingers & Taylor, 1992; Morrill, 2007; Westcombe, Franco, & Shaw, 2006). These challenges are intercorrelated and need to be addressed holistically.

Collins et al. (2019) identify some sources of the challenges: the current structure of academia, the negative perception of qualitative approaches, and the lack of appropriate educational courses available. Similarly, Morrill (2007) points out five challenges that the PSM community is facing as follows:

- Stagnation in PSM development within academia
- Small graduate OR pool interested in PSM, Soft OR
- Difficulties in developing PSM skills
- Lack of a buy-in from the wider OR community
- Small active in the community

These five challenges stem from the practitioner’s perspective. It is worth noting that although there are records of success in the literature, they are considered anecdotal reports. Collins et al.

(2019) and Montibeller and Belton (2006) confirm that there is a need to empirically show the effectiveness of the methods.

Robinson (2007) observes that learning PSM without an apprenticeship – due to a few advocates in the community – may be one of the sources of the issue. It is one of the most significant challenges because “there seems to be a very limited succession” (Robinson, 2007, p. 690). Thus, the appropriate PSM courses are needed, as advocated in Collins et al. (2019). Carreras and Kaur (2011) propose the experiential approach as one of the ways to establish the necessity of teaching PSM. The authors believe that the approach is crucial to the development of PSM skills. The profound establishment of the necessity in teaching PSM may bridge the gap that is discussed in Collins et al. (2019); Mingers (2011); Morrill (2007); Robinson (2007). A strong foundation of PSM education has an ability to attract new practitioners and researchers to the field (Westcombe et al., 2006). Collins et al. (2019) also propose case studies as one of the contributions to a better PSM education.

Collins et al. (2019) add that it is difficult to show whether PSM interventions produce a tangible outcome as a traditional OR does. However, the purpose of PSM is different from the traditional OR, as discussed in Ackoff (1977) and Rosenhead (1996). Mingers (2011) believes that PSM “are well developed theoretically, have been used successfully in a wide variety of practical problem situations and have generated an active scholarly literature” (p. 730). For an effective problem-solving intervention, it is better to take sometimes to structure/formulate the *right* problem before solving it, rather than solving the *wrong* problem.

An inadequate of a buy-in from the community is one of the most critical challenges. As indicated earlier, it is believed that the PSM interventions take a long time, and there are no clear benefits from the use of that time (Jenkins, 1998). Having no clear benefits impacts a buy-in from the wider community, especially from the industry. It is mainly because the industry normally operates in a benefit-optimized approach. However, Westcombe et al. (2006) believe that, if done correctly, “PSM can have a real impact on organizational development” (p.778). Leonhardt Kjærgaard and Blegind Jensen (2014) also note that, with a good facilitator and good practice of the participants, the outcome of PSM interventions will be worthy of spent time. This challenge is not necessarily unique to the PSM community. Thaviphoke and Collins (2019a) address this problem and point out that there is a similar issue in the Modeling and Simulation (M&S) community as well.

Mingers (2011) and Marttunen et al. (2017) are convinced that a PSM can work effectively in complex practical situations and has a presence in the academic literature, strongly in the UK. However, PSM is not yet recognized everywhere, especially in the US (Mingers, 2011; Robinson, 2007; Westcombe et al., 2006). It has been commonly assumed, at least in the US, that the method can only structure a problem, not solve or resolve it. In other words, there is no trust in the methods. Some of the comments from Mingers (2011, pp. 737-738), such as “lack the hallmark use of mathematical models” or “lacks the objectivity” are mentioned. The author admits that PSM can be seen as a weak method regarding a lack of mathematical uses – at least in the US. Table 5 concludes some of the main challenges in the field.

Table 5. A Summary of the Main Challenges in PSM Community adapted from Morrill (2007)

Main challenges	Some supportive arguments
1. Stagnation in PSM development in academia,	There is a need for the establishment of the necessity of teaching PSM (Carreras & Kaur, 2011).
2. Small graduate OR pool interested in PSM,	There is a lack of apprenticeship (Robinson, 2007).
3. Difficulties in developing soft skill,	It is difficult to show tangible outcomes from the PSM intervention (Collins et al., 2019). There is a lack of confidence in PSM (Mingers & Taylor, 1992).
4. Lack of a buy-in from the wider community,	There is a need to empirically show the effectiveness of PSM. Also, researchers strongly believe that a strong education will help attract practitioners, researchers, and clients to the field (Jenkins, 1998; Montibeller & Belton, 2006; Westcombe et al., 2006).
5. Small active in the community	There is a lack of trust in the methods in the US (Mingers, 2011; Robinson, 2007).

As shown in Table 5, all challenges are interconnected. As discussed in Collins et al. (2019), showing a tangible outcome from the PSM intervention may address some of the challenges. It is confirmed by Finlay (1998); White (2006), and Franco (2007) that an empirical investigation on the effectiveness of PSM has the potential to address these challenges. The positive outcome of such investigations could contribute to the more acceptance of PSM in the US, as discussed in Mingers (2011) and Robinson (2007).

Attempts to Evaluate PSM

This section reviews the efforts that researchers attempt to evaluate the application of PSM. As discussed earlier, there is a desire to evaluate the effectiveness of PSM to address the existed challenges in the field. PSM is widely applied in OR endeavors, heavily in the UK. The previous section indicates the evidences of some positive outcomes after PSM interventions. However, most reports of the evaluation of the methods are anecdotal. Those reports mainly focus on the usability of the methods themselves, not the impact that these methods could make on a problematic situation. Moreover, most of the reports are the outcome of an action research approach. In other words, the majority of the reports are based on researchers' perceptions (Lami & Tavella, 2019). Literature reveals three types of PSM evaluation: using a framework, action research, and empirical approach. Most of the reports form the first two approaches are considered anecdotal. There is a lack of empirical evidence of the effectiveness of PSM (Cunha & Morais, 2017; Jenkins, 1998; Montibeller & Belton, 2006; Westcombe et al., 2006).

The use of a framework is reported in the literature. Midgley et al. (2013) identify a framework to evaluate PSM intervention. The framework consists of four different aspects: method, context, purpose, and outcomes. In other words, the framework aims to evaluate how good of the *method(s)* by addressing the *purpose(s)*, the enablers or constraints in the *context*, some of the anticipated or unanticipated *outcomes* of the focusing problem. This framework can be viewed as an exploratory tool. Sørensen and Vidal (2008) also evaluate six PSM interventions using a conceptual framework based on interactive planning from Ackoff (2001). The evaluation mainly focuses on the practical usability of the method, not the effect that PSM interventions impacts on a problem.

Action research approach is the main evaluation reported in the literature. White (2006) believes that the theory-based approach is appropriate to evaluate the PSM interventions. One of the findings indicates the importance of the facilitator or analyst on the outcome of an intervention. The importance of a well-rounded facilitator in an effective PSM intervention is widely discussed in the literature (Cronin et al., 2014; Midgley et al., 2013; Rosenhead & Mingers, 2001). A good facilitator should be able to "abandon the expert role (i.e., expertise in methodology and translating it into practical explanation of process) and allow the participants to be the experts in what they know" (Lami & Tavella, 2019, p. 1023).

Given the complexity of PSM intervention, the auto-ethnography is also recommended as a tool to understand PSM intervention (Franco, 2007; White, 2006). A finding from ethnography is "typically relates to the life experiences and thoughts, views and beliefs of the analyst/facilitator" (White, 2006, p. 854). Following the auto-ethnography approach, Franco (2007) conducts an evaluation using tape-recorded, semi-structured interviews and observations to investigate the suitability and impact of PSM in a multi-organizational setting operating within the UK construction industry. The results indicate that a PSM intervention generates: the improvement of problem understanding, a clearer views of the options for actions, a strong commitment to the implementations, and the increased "members' awareness of the advantages of mutual accommodations" (Franco, 2007, p. 766).

White, Burger, and Yearworth (2016) also propose an activity theory as one of the ways to understand the behavior of PSM intervention. The authors apply the ethnomethodological approach to study the process of the intervention through a video analysis along with questionnaires, interviews, and observations. Ethnomethodology is "the study of a particular subject matter: the body of knowledge and the range of procedures and considerations by means of which the ordinary members of society make sense of, find their way about in, and act on the circumstances in which they find themselves" (Heritage, 1984, p. 4). In other words, it is an open-ended reference to any kind of sense-making approach. The authors find that collective learning – which includes language instruments, visualized models, written agreements and rules for action, and shared understanding – is present during the observation. Moreover, "it appears that interventions are to be understood as activity systems, oriented towards objectives, in a flux of changing circumstances and networks" (White et al., 2016, p. 997). Until now, most of the studies apply qualitative research methodology to study the impact of PSM interventions on the participants. The results of the approach can be considered somewhat anecdotal, as stated earlier.

For the quantitative approach, Cunha and Morais (2017) conduct a comparative study between the PSM and no PSM applications in a problem-solving process. Seventy-two college students participate in the research. The experiment is designed to compare the differences between control and treatment groups. The treatment is PSM, while the control has no specific method for discussion. The group with PSM treatment exhibits a better focus and creativity than the control group. The use of a PSM contributes to a better understanding of the focusing problem. Moreover, based on the observations, a facilitator is one of the most important contributions to the outcome of the experiment. This result is aligned with the findings from White (2006) and Franco (2007). The authors also report the difficulties in the measurement of the outcome of the interventions. It is due to the subjectivity of the data collection and the nature of PSM. However, meaningful results are found.

Wu, Wang, Grotzer, Liu, and Johnson (2016) also conduct a two-group experiment to assess whether there is any difference between a control group and a treatment group. The control group applies a verbal-text approach, while a treatment group uses a PSM approach. Four simulated cases were presented to both groups. They have over four weeks to finish the tasks. Fifty-two subjects participate in the experiment. The results show that the PSM group outperformed the verbal-text group in problem-solving performance (mean difference = 0.16, $t = 2.89$, $df = 49$, $p<0.05$). The authors also conclude that visual representation has a promising advantage in representing complexity comparing to a verbal-text approach.

Similarly, Lami and Tavella (2019) conduct an exploratory, quasi-experimental research to assess the difference between non-PSM supported and PSM supported groups. Seventy-five students participate in this study. Participants are separated into three groups (two PSMs and one non-PSM). All groups are asked to complete the same task. The experiment in each group is conducted simultaneously in three different classrooms (SSM, SCA, and non-PSM). The questionnaire from Midgley et al. (2013) is used as a part of the measurement tool. One of the findings reveals that participants in a non-PSM group exhibit higher creativity than a PSM group. This result contradicts with the one found in Cunha and Morais (2017). However, Lami and Tavella (2019) admit that a non-PSM group was exposed to PSM knowledge at the beginning of the study. PSM is introduced to the participants before they are assigned to a random group. Therefore, it can be concluded that the results could have been developed from self-facilitation behavior in a non-PSM group. A more controlled methodology is needed to ensure the relevant findings.

Strategic Options Development Analysis (SODA)

There are numerous methodologies, methods, and techniques that have been applied under the PSM umbrella (Rosenhead & Mingers, 2001). As mentioned earlier, one of the main purposes of PSM is to capture the richness of problematic situations (Pidd, 1988). Strategic Options Development Analysis (SODA) is designed to deal with a messy problem (Eden, 1989). It is applied in a group of people who “may have difficulties in defining and structuring their perception of a problematic situation” (Sørensen & Vidal, 2008, p. 10). SODA acknowledges the existence of multiple perspectives and provides a framework to structure a problematic situation for a group (McKay & Marshall, 2005).

SODA helps a group to build an overall understanding of a particular issue (Ackermann & Eden, 2001). The authors also argue that SODA is mainly applied to explore future scenarios and stakeholder management. Some authors call SODA a “sense-making” tool (Thaviphoke & Collins, 2019a) or a quick-and-dirty approach (Shaw, 2006). An outcome of SODA generates share understanding, which is the holistic properties of the aggregated information among people in a group (Ackermann & Eden, 2001; Eden, 1989; Georgiou, 2011; McKay & Marshall, 2005; Thaviphoke & Hester, 2018; Westcombe, 2002b). It is worth noting that SODA is one of the most widely used PSM.

Rosenhead (1996) defines SODA as one of the problem identification methods, which is applied as a modeling device, along with a facilitator, to guide the individuals or a group toward the desired situation. One of the most important roles of a facilitator is to bring together different perspectives, analyze the meaning of those perspectives, and formulate a process of agreeing on an action for the group of people (Eden, 1989). SODA serves as an exploratory method to gain an overall understanding of the problematic situation. An outcome of SODA can help to mitigate the communication problems in a group.

Thaviphoke and Collins (2019b) argue that, in some context, the primary purpose of SODA is not necessarily a problem-solving tool but rather a reflective device of a problematic situation. Eden (1988) defines it as a reflective problem-solving. With the nature of SODA, it is possible to “determine the basis for pulling a mess into a system of interacting issues” (Ackermann & Eden, 2001, p. 155). Marttunen et al. (2017) agree and identify three expected outcomes of SODA, which are a defined boundary of the focusing problem, the identifications of criteria, and the development of alternatives.

Eden (1989) identifies four different conditions where SODA would be appropriately applied:

- There is a need to manage a social process: the potential tensions between individuals in the problem-solving process
- A small number of significant stakeholders (3-10 persons)
- There is a need to explore the problematic situation as opposed to the linear and deterministic approach
- There is a need to include the stakeholders into the process via the workshops

The focus on an individual perspective within SODA is derived from the personal construct theory (Kelly, 1955). The theory argues that individuals will try to “make sense” of the surroundings to “manage and control” those surroundings. In an attempt to capture and represent each individual construct, the cognitive mapping concept is introduced in SODA (Ackermann & Eden, 2001; Eden, 1989). A cognitive map is a network of related concepts that represents the discourse of a person or a group (Eden, 1989; Montibeller & Belton, 2006). Leonhardt Kjærgaard and Blegind Jensen (2014) add that “cognitive maps provide the possibility of representing users’ thoughts, ideas, and critical comments about a technology and other related aspects” (p. 1110). Since a combined cognitive map provides a form of shared understanding, it helps a group of stakeholders to make effective decisions (Pidd, 2009). McKay and Marshall (2005) also note that SODA supports working with individuals and then groups.

A cognitive map is made of nodes and arrows (Eden, 1988). More specifically, it is a network of nodes and linked by arrows. The network is generated based on how a person views a focusing situation (Eden, 1989). A ***node*** represents a statement or concept which, in SODA, is written in the form of two contrasting poles where one pole represents the positive part of the concept and the second its psychological opposite – a bipolar construct (Ackermann & Eden, 2001). For example, to depict one concept on a map (spend money on staff development … buying a new machine). The example can be read as "spend money on staff development *rather than* buying a new machine." This bipolar concept generates a chain of argument (Eden & Ackermann, 2001). It is worth noting that there is a need for proper training to understand the bipolar concept in SODA. An ***arrow*** represents the means-end relationships among nodes. The relationships can be both positive and negative. For an arrow, a positive sign shows a positive causal relationship among the nodes (e.g., more staffs lead to more products). A negative sign indicates a negative connection among the nodes (e.g., more staffs lead to less space in the office). In conclusion, a SODA map is a network map of ideas that are connected by arrows. The nodes that have arrows pointing in often represent goals or objectives, while the nodes at the tail of arrows usually represent actions (McKay & Marshall, 2005).

A cognitive map is considered a model of the system of concepts. It is a language-based model that is used by the individuals to convey their understandings toward the focusing problem (Eden, 1989; McKay & Marshall, 2005). Leonhardt Kjærgaard and Blegind Jensen (2014) add that the cognitive mapping process helps a decision-maker dealing with a more sophisticated decision on organizational changes. Within a group environment, the overall understanding of a problem can be captured in the form of a combined cognitive map – a mess representation (Thaviphoke & Hester, 2018).

SODA is performed to manage a mess, and it is frequently applied with other methods (Mingers & Brocklesby, 1997). Rosenhead (1996) applies SODA as a front-end mechanism followed by System Dynamics (SD) in a legal problem context. The result of the intervention is the validated SODA map, which generates powerful feedback loops (98 in all) to construct the influence diagram for a SD model. Marttunen et al. (2017) also report the applications of SODA together with Multi-Criteria Decision Analysis (MCDA). It is concluded that SODA can be practically applied to a complex problem. The authors also provide some positive and negative attributes of SODA, as shown in Table 6.

Table 6. SODA Pros and Cons (adapted from Marttunen et al. 2017, p. 7)

Pros	Cons
Helps to surface and structure an individual's or a group's collective ideas using natural language.	In need of a skillful facilitator(s).
Helps to reach an overall understanding from different perspectives.	In need of a special software if the map is big.
	Merging individual maps is challenging.

Table 6 indicates that most of the cons stem from the need for a skillful facilitator. As discussed earlier, the need for strong facilitation skills with a profound understanding of the methods tends to be one of the most concerns. White (2006) discusses the importance of a facilitator stating that "the analyst may have brought a whole series of world experience to play in the intervention" (p.853). There is a need for a well-rounded facilitator to ensure the effectiveness of the intervention. Furthermore, Leonhardt Kjærgaard and Blegind Jensen (2014) also mention that the method can be perceived as a time-consuming and demanding intervention. However, with a good facilitator and a good practice, Rosenhead and Mingers (2001) elaborate that the intervention will provide better details in a systematic process, which is believed to outweigh the invested time.

SODA Process

There is no specific way of conducting SODA. Eden (1989) argues that a SODA process can be adapted based on the context of the focusing problem: organization style, a culture of the group, or the time constraints. Pidd (2009) categorizes SODA into two approaches – *SODA I and SODA II*. Both approaches provide a platform for a group to learn about the focusing situation before reaching some forms of consensus in a decision-making process (Ackermann & Eden, 2001). *SODA I* and *SODA II* processes are one of the focuses of this dissertation.

SODA I has two main components: map developments (individual and group) followed by a group discussion (Eden & Ackermann, 2001). First, through an interview with a facilitator, each individual will be asked to develop a cognitive map that portrays their view toward the facing situation (McKay & Marshall, 2005). As outlined earlier, an individual cognitive map is a subjective representation of the situation from that individual's perspective. By applying the cognitive mapping concept, individuals can graphically show how they perceive the issues they are facing. In other words, a cognitive map shows an individual's reflection of the focusing situation. A map indicates concepts and relations that are subjectively meaningful for the one who created it (Leonhardt Kjærgaard & Blegind Jensen, 2014). It is worth noting that this is not a binary (right or wrong) concept.

After all individuals in a group finish the mapping process, all maps will be combined into a group map by a facilitator. A facilitator will search for the differences and similarities among the individual maps to develop a group map. A group map contains all relevant concepts from each individual's map. If done correctly, all individuals will see their concepts/ideas on a group map. Thus, a group map increases the individual's ownership of the problem (Franco, 2007). It is suggested that the use of the individual's own words will increase the ownership of the individual to the group map (Pidd, 2009). The ownership of the problem could lead to a high level of commitment in a group.

It is one of the facilitator's responsibilities to make sure that all the important concepts from the individual maps are present on a group map (Westcombe, 2002a). A group map portrays an appropriate dialogue that enables a group to have the discussions and negotiations to reach a common understanding (Eden, 1989). Simply put, if the individual maps are considered a subjective view of an individual, a group map is an intersubjective view of a group (McKay & Marshall, 2005). Pidd (2009) emphasizes that the main objective of going through a group map is for the participants to "see their views as part of a larger picture, and also start to understand the concerns of other people" (p. 130).

The second part of SODA I is mainly a constructive discussion and negotiation among individuals, which is led by a facilitator. The core purpose of the discussion is to create a common understanding of the situation through debates and negotiations. A generation of a group map potentially creates the interactions which "can form a valuable contribution for groups of users to get inspiration from one other" (Leonhardt Kjærgaard & Blegind Jensen, 2014, p. 1109). A group map development not only reveals synergistic interactions among concepts, but it can also potentially visualize possible conflicting interpretations among individuals in a group (Eden, 1989). One of the most important objectives of a group map is to help a group reach a form of consensus.

SODA II is applied by starting with the group rather than starting with individuals. A team, along with a facilitator, build a group map that represents their perspectives toward a focusing problem. This group map, similar to one in SODA I, will be used by a skillful facilitator to help a group reach a form of consensus. Pidd (2009) notes that SODA II is usually applied together with the help of computer software. A software can help a group to avoid a group-think dilemma (Westcombe, 2002b). However, Eden (1989) argues that the software is an “integral, but not essential, part of the process” (p. 27). Working as a team can generate a real-time interaction that encourages more contributions from members in a group (Ackermann & Eden, 2001; Rouwette, Bastings, & Blokker, 2011). As mentioned earlier, SODA can be adapted based on the problem context.

Knowledge Gap

As discussed earlier, there are some indications that PSM is useful in OR literature (Checkland, 2006; Rosenhead & Mingers, 2001) and reports of the evaluation of the methods exist (Cunha & Morais, 2017; Franco, 2007; Midgley et al., 2013; Mingers, 2011; Sørensen & Vidal, 2008; White, 2006; White et al., 2016; Wu et al., 2016). However, most of them are anecdotal reports. Shaw (2006) notes that PSM literature focuses more on the development and deployment of the methods. There is not much of an effort in identifying the contribution of the components of PSM in the problem-solving process (Yearworth & White, 2014). Mingers (2011) suggests that the initiation of “a serious research program to evaluate the contribution of qualitative OR approaches to problem-solving and decision-making in a complex situation” (p. 739) is needed. The empirical evaluation is also called by White et al. (2016), Westcombe (2002b), Finlay (1998), and Collins et al. (2019); Volkema (1983). The lack of empirical evidence supporting the utility of PSM may inhibit the widespread use of the approach, especially in the US (Mingers, 2011; Robinson, 2007). Also, the lack of a buy-in from the wider community, as discussed in the previous sections.

In this research, the empirical investigation of the effectiveness of a PSM in addressing a messy problem is conducted. This research addresses the knowledge gap where there is a lack of empirical evidence of the effectiveness of PSM. The result of this experimental investigation could make a big impact on PSM research. The author believe that the importance of PSM effectiveness on a problem-solving process could be made explicit in the literature. The attempt in this research is only a small step of a bigger aspiration – to make a better decision and avoid committing an error.

Conceptual Model of the Experiment

This research explores the relationship between the use of a PSM and a group consensus, through problem-sovling confidence, in a messy problem. To demonstrate the effectiveness of a PSM, Strategic Options Development Analysis (SODA) is selected as a treatment in this experiment. SODA is one of the widely-used PSM (Eden, 1989; Ormerod, 2018; Rosenhead & Mingers, 2001), and the method was applied in previous research (Cunha & Morais, 2017; Wu et al., 2016).

Within a group environment (i.e., a mess), Orive (1988) and Koriat (2018) identify the relationships between a level of confidence of the members and a group consensus. Orive (1988) argues that group members hold greater confidence when there is a consensus in a group. Specifically, it has been found that the average confidence in a group increases when the consensus is present (Koriat, 2018). Thus, it can be implied that a high level of confidence in group members can be a proxy to indicate that the consensus is achieved in a group. Given that there is no optimal solution in a mess, one of the successes when dealing with a mess is to reach a group consensus.

Confidence is one of the relevant factors that could influence an individual's decision. Thornton (1995) claims that confidence may be a more critical component than a required skill in an effective problem-solving process (as cited in Larson, Scott, Neville, & Knodel, 1998). However, it should be noted that showing a positive self-appraisal does not guarantee the effective performance unless the individual has particular skill to solve the problem (Heppner, Witty, & Dixon, 2004). Chang, D'Zurilla, and Sanna (2004) also note that confidence is theoretically meaningful in the problem-solving process. Decision confidence is a subjective estimation of whether the decision is right or wrong (Boldt, Schiffer, Waszak, & Yeung, 2019). It influences individual behavior through its impact on choice (i.e., problem-solving). Bandura (1986) argues that a confidence is a person’s belief in problem-solving ability. It strongly influences their success in problem-solving process within ambiguous situations (as cited in Larson et al., 1998). It should be noted that the notions of ambiguous situations and messy problems are highly overlapped. As Pidd (2009) defines a mess as a “set of circumstances in which there is extreme ambiguity and in which there may well be disagreement” (p. 46).

PSM intervention is a complex phenomenon (Midgley et al., 2013; Mingers, 2000; White, 2006). As discussed earlier, the outcome of the PSM intervention can be influenced by many factors such as a facilitator, the contextual factors, and other subjective aspects. Critical to the experimental design is that extraneous factors be sufficiently controlled to ensure that conclusive results are obtained in the study (i.e., homogeneity within groups). All the variables (dependent, independent, and controlled) will be elaborated later in this document.

A controlled experiment is implemented in this research where SODA is applied as a PSM intervention. Also, this experiment is conducted in a small group environment. Watson, DeSanctis, and Poole (1988) apply a group decision support system to assess consensus in groups of three and four persons. The authors conclude that the impact of a group decision support tool in a small group (three to four individuals) may be more significant than the impact in the larger-size group. Eden (1989) also mentions that SODA is more effective with a small number of significant stakeholders. There is a control group and two treatment groups in the design. The treatments of this experiment are the SODA processes, as shown in Figure 2. The treatment groups will be using SODA processes to complete a decision task, while the control group will complete the same task without using SODA process. The difference between the outcome from the control and treatment groups is evaluated to assess the effectiveness of the manipulation (i.e., SODA processes).

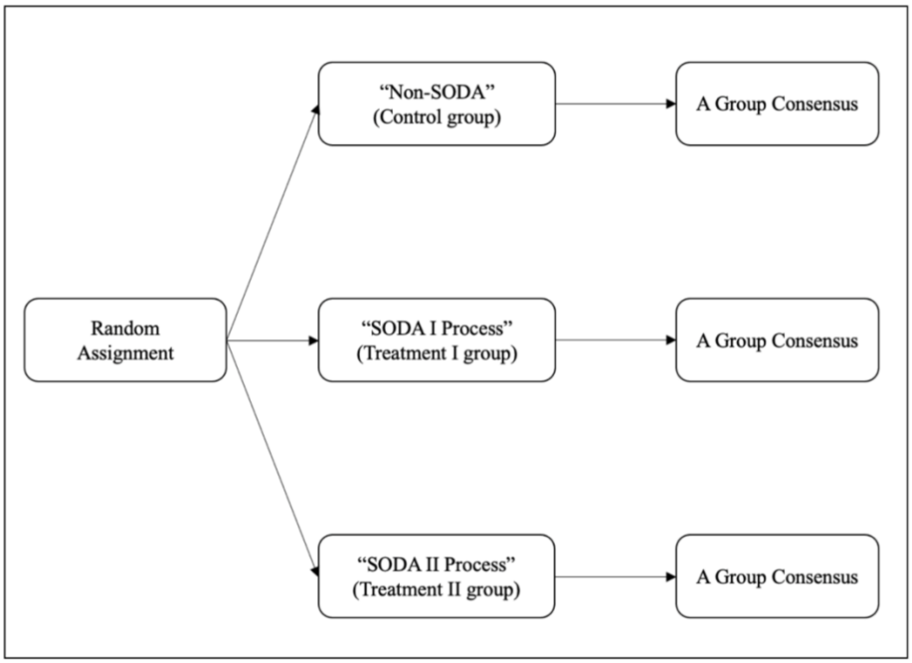

Figure 2. Conceptual Model

Figure 2 presents a three-group experiment, control and treatment groups. As elaborated earlier, Pidd (2009) categorizes SODA into two different processes – SODA I and SODA II. Therefore, this present research simulates the process of the two as an experimental treatment. A regular group discussion is applied in a control group. As shown in Figure 2, the independent variable is a decision condition, and the dependent variable is a group consensus. The result of the study is expected to disclose the impact of SODA on a group decision-making.

In conclusion, the objective of this research is to answer the following research question: Does a SODA process affect the development of a group consensus in a messy problem?

CHAPTER 3

METHODOLOGY

Purpose of the Research

The goal of this research is to show the value of the Problem Structuring Methods (PSM), specifically Strategic Options Development and Analysis (SODA) as an effective decision tool in a messy problem. As elaborated earlier, a messy problem is a "systems of problems with multiple stakeholders who may hold quite different view of what is feasible and desirable" (Pidd, 2009, p. 46). PSM has evolved within Operations Research (OR) community "to better deal with messy, wicked and complex problems that are not amenable to the traditional, largely quantitative, OR techniques" (Kotiadis & Mingers, 2006, p. 856). The methods are widely used to address a problem that involves social elements (i.e., messy problem) (Rosenhead & Mingers, 2001). Within a PSM umbrella, SODA is developed to help a group to create some forms of consensus by using the cognitive mapping technique (Eden & Ackermann, 2001). SODA is also designed to offer supports to a group decision making in a messy problem (Ackermann & Eden, 2001).

As mentioned earlier, PSMs are widely accepted, yet researchers have identified some challenges that the field is facing (Ackermann et al., 2014; Checkland, 2006; Collins et al., 2019; Eden & Ackermann, 2006; Keys, 2006; Mingers, 2011; Mingers & Taylor, 1992; Morrill, 2007; Westcombe et al., 2006). One of the challenges is the lack of a tangible outcome of PSM intervention. There is a need to shows the effectiveness of the methods (Collins et al., 2019; Montibeller & Belton, 2006). Therefore, an experimental research approach is recommended (Cunha & Morais, 2017; Herrera, McCardle-Keurentjes, & Videira, 2016; Lami & Tavella, 2019).

Research Hypotheses

A hypothesis-testing approach is a deductive process of logical inference (Tanner, 2018). This research approach can address the challenge regarding the need for empirical research in the PSM community (Collins et al., 2019; Morrill, 2007; Westcombe et al., 2006). As stated earlier, the research question is formulated from the reported challenges regarding a lack of confidence in PSM and a need for tangible outcomes of PSM intervention (Collins et al., 2019; Mingers & Taylor, 1992; Morrill, 2007).

As elaborated earlier, in a messy situation, confidence can be considered a proxy of reaching a group consensus (Koriat, 2018). The review of the literature also shows the reports of SODA helping a group to reach some forms of consensus (Ackermann & Eden, 2001; Eden & Ackermann, 2001; Rosenhead & Mingers, 2001). The objective of this present study is to answer the following research question:

> "Does a SODA process affect the development of a group consensus in a messy problem?"

The research question is explored through problem-solving confidence as a proxy to indicate the development of a group consensus. The following sections describe the research hypotheses in more detail. Note that a null hypothesis will be subbed by "o," whereas the alternative hypothesis will be subbed by "a." All the hypotheses in this study are related to overall group means. Four alternative hypotheses are the followings:

H_{a1}: The average level of problem-solving confidence of the members in a group using SODA process will be different than when SODA process is used

H_{a2}: The average level of problem-solving confidence of the members in a group using SODA I process will be different than when SODA process is used

H_{a3}: The average level of problem-solving confidence of the members in a group using SODA II process will be different than when SODA process is used

H_{a4}: The average level of problem-solving confidence of the members between a group using the SODA I process and in a group using the SODA II process will be different

The hypotheses are formulated from the notion that SODA generates a framework that contributes to a shared understanding of the focusing problem (Rosenhead & Mingers, 2001). A higher level of shared understanding within a messy situation should lead to higher confidence. Therefore, problem-solving confidence levels in treatment groups are expected to be higher than the one in a control group.

Given the alternative hypotheses, the null hypotheses can be formulated as follows:

H_{o1}: There is no difference in the problem-solving confidence between the group that uses the SODA process and the group that does not use the SODA process

H_{o2}: There is no difference in the problem-solving confidence between the group that uses the SODA I process and the group that does not use the SODA process

H_{o3}: There is no difference in the problem-solving confidence between the group that uses the SODA II process and the group that does not use the SODA process

H_{o4}: There is no difference in problem-solving confidence of the members between a group using the SODA I process and a group using the SODA II process

The result of this study will contribute to a better understanding of how the SODA process affects the outcome of the group decision-making. Moreover, the positive outcome can address some of the challenges in the field as presented earlier in this document. This research aims to answer its questions through the experiment.

Experimental Design

Research Environment

The present experiment was conducted at a large university in the eastern region of the United States. Participants in this current study were college students. Students were recruited via invitation or email. As shown in Figure 2, there are three experimental conditions – Treatment I, treatment II, and controlled condition. Within each condition, participants were asked to complete the decision task in a three-persons group. All facilitations were done with one facilitator and a predesigned script. A validated instrument was used to collect the data.

Approach

The research methodology is based on a controlled experimental approach to assess a group consensus using problem-solving confidence of the members in a group decision-making. The effectiveness of a group decision support system on a group decision-making process has been shown via research in a laboratory setting (Watson et al., 1988). The experimental research allows a researcher to manipulate an independent variable to assess its impact on dependent variables. The controlled environment permits a more precise assessment of the impact of an intentional manipulation on the outcomes of the experiment. Sprinthall (2007) elaborates that, in experimental research, the subjects are randomly selected from a population and measured on the dependent variable(s) *only* after the manipulation of the independent variable. The independent variable of this experiment is a decision-making condition (Non-SODA and SODA), while the dependent variable is the problem-solving confidence of members in a group. The primary purpose of the study is to investigate the effect of SODA on the problem-solving confidence of participants in a messy situation. Group formation is designed to simulate a messy situation which will be elaborated later.

The experiment groups in this present experimental design are separated into two conditions, as shown in Figure 3.

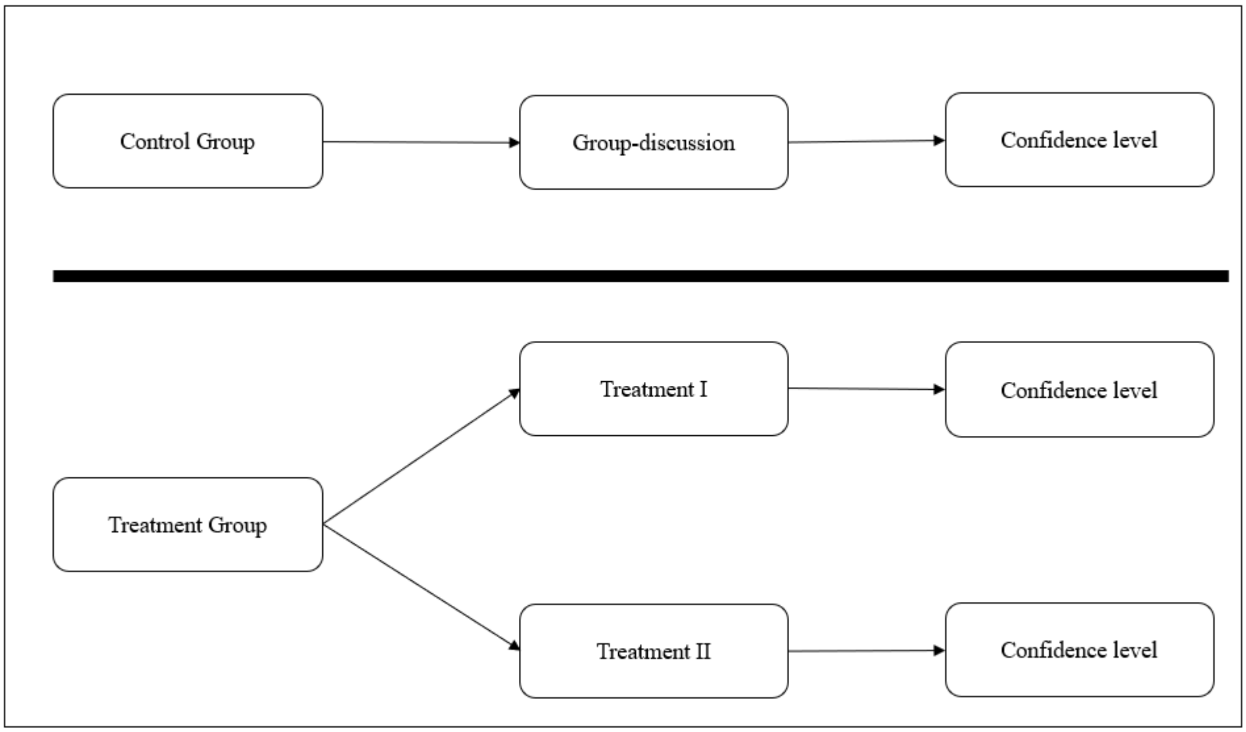

Figure 3. Experimental Design

As presented in Figure 3, there are two experimental conditions (treatment I and treatment II) and one control condition (group discussion) in this experiment. All the participating groups in all three conditions were formed in the same group formation. The three different conditions will be discussed later in this document.

Relevant Variables

Dependent variable. Problem-solving confidence was a dependent variable in this experiment. As elaborated earlier, a level of confidence of the members can be used as a proxy to indicate that a group consensus is reached. Problem-solving confidence was evaluated after the completion of a group decision task. Problem Solving Inventory was adapted to serve the purpose of this study, and applied to assess the problem-solving confidence of the participants.

The Problem-Solving Inventory (PSI) (Heppner & Petersen, 1982) was used to collect problem-solving confidence in this experiment. PSI is a reliable instrument that measures an individual's perceptions of their problem-solving behaviors (Heppner et al., 2004; Tesone, Ross, & Upchurch, 2010). The PSI has been widely used in research study, "which have served to provide evidence of its validity (Phillips, Pazienza, & Ferrin, 1984, p. 499)." The instrument assesses peoples' perceptions of their problem-solving beliefs and styles (Heppner et al., 2004). PSI is a widely used self-report measure in a problem-solving process (Heppner & Baker, 1997). Heppner et al. (2004) review 120 studies of PSI applications and conclude that PSI provides "useful information for structured problem interventions (p.414)." PSI consists of 35 six-point Likert items – ranging from 1 = Strongly Agree to 6 = Strongly Disagree – which covers three constructs. Those three constructs are Problem-solving confidences, Approach-avoidance style, and Personal control. Heppner et al. (2004) state that the three constructs are "independent enough to be considered as separate factors" (p. 353).

Problem-solving confidence construct measures an individual's self-assurance, beliefs, and trust in an ability to cope with a range of problems (Heppner et al., 2004). The notion of problem-solving confidence is also conceptually consistent with the concept of self-efficacy from Bandura (Karbalaei, Abdollahi, Abu, Nor, & Ismail, 2013). Maydeu-Olivares and D'Zurilla (1997) find that ten out of eleven items tap primarily problem-solving efficacy expectancies (i.e., the factor is directly related to the social problem-solving theory). The authors also recommend that the “scale should be used when an investigator is interested in a specific measure of the problem-solving self-efficacy” (Maydeu-Olivares & D'Zurilla, 1997, p. 213). Most of the previous research has used the sum of PSI score to examine problem-solving appraisal (Heppner & Lee, 2002; Heppner et al., 2004). Wood and Crowe (1997) use some of the PSI score to assess the confidence level of college students who involve in the problem-solving program. Pinar, Yildirim, and Sayin (2018) confirm that the PSI scale is evaluated on the total score. Thus, total score will be evaluated in this experiment.

This experiment focuses on problem-solving confidence of the members in a group. Therefore, it measures the problem-solving confidence using 11-item problem-solving confidence construct from PSI. Some adaptations were made to serve the purpose of the study properly. A high level of problem-solving confidence is represented by a low score from PSI and vice versa. Heppner and Petersen (1982) state that “low scores indicate behaviors and attitudes typically associated with successful problem solving (p.67).” Heppner and Lee (2002) confirm that higher scores mean a lack of problem-solving confidence. Thus, the lower scores show high levels of problem-solving confidence (Kourmousi, Xythali, Theologitou, & Koutras, 2016). For example, responding ‘Strongly agree (1)’ to an item “Solving this problem in a group using the given approach, I am almost certain that we can solve the problem” means that the participant has a high level of confidence. On the other hand, if the participant responds ‘Strongly disagree (6)’, it means that the participant has a low level of confidence. The full list of the questionnaire used in this experiment can be found in Appendix D. The Cronbach’s alpha of the instrument used in this current experiment showed internal consistency ($\alpha = 0.826$), as shown in Appendix F.

Independent variable. The independent variable of this study was a group decision-making condition (SODA and Non-SODA). There were three different conditions, as elaborated earlier. The main purpose of the experiment was to investigate the difference in problem-solving confidence of members between control and treatment groups.

Controlled variables. This study attempted to control the following: decision task, group size, facilitation, and decision-making environment. The decision task was based on the survival simulation scenario (Winter Survival Exercise), which was widely used in group decision experiments (Johnson & Johnson, 1982; Joshi, Davis, Kathuria, & Weidner, 2005; Stapleton, 2007). The chosen decision task has a pre-determined score from subject matter experts. This task provides a constant structure and difficulty for all the three decision-making conditions in this study. It should be noted that the score is not the main focus of this current study (more details about the task are elaborated next section). The group size was kept constant, a group of three, for all conditions. The facilitation in this study was controlled. There was one facilitator in this study. The facilitator effect was controlled by using a predesigned script (Appendix E) for every condition in the experiment. The script was used to ensure the consistency of the process among the conditions (Herrera et al., 2016). The given cognitive maps are also considered a controlled input for the facilitation for both treatment groups. The cognitive maps were given to the participant because of the limited experiment time. Also, Stull and Mayer (2007) find that participants show better understanding with the provided material (rather than creating their own) in a similar type of experiment. For the decision-making environment, all decision-making conditions were conducted in a confined space with a facilitator and a group. In conclusion, the main difference among the groups is the decision-making conditions (i.e., the independent variable) as elaborated earlier.

Decision Task

The Winter Survival Exercise (WSE) is designed to evaluate the understanding of the dynamics problem (i.e., messy problem) concerning decision making and problem-solving (Joshi et al., 2005). WSE is an experiential exercise in which the participants are put into the scenario of surviving a midwinter crash-landing of a plane in Minnesota. They are asked to rank 15 items in order of importance to survive in the mentioned scenario. Originally, after finishing the task, the participants' scores are evaluated by the Subject Matter Expert's (SME) scale. The lower the absolute difference, the closer to the ones provided by SME. In other words, "a lower score indicates better decisions (Joshi et al., 2005, p. 678)." The total score indicates the quality of decisions. However, the quality of the decision (score) is not the focus of this study. One of the reason is that there is no absolute solution in a messy problem as elaborated earlier. The focus of this research is to evaluate whether a group consensus is achieved through the use of a PSM. Therefore, this exercise is used as a controlled variable in this present experiment.

The original form of this exercise is focused on the effectiveness of group problem solving, team building, and communication (Johnson & Johnson, 1982). This exercise was selected in this experiment because the scenario presents a complex problem involving strategy-building activity and it is widely used in a group decision experiment (Joshi et al., 2005). The exercise can be considered applicable scenarios for the Strategic Options Development Analysis (SODA) since it involves many social elements that could be considered a messy situation.

Sampling and Group Formation

Samples

Participants were college students from a large university in the eastern region of the United States. The use of student data to evaluate PSM is reported in the literature (Cunha &

Morais, 2017; Lami & Tavella, 2019; Wu et al., 2016). A sample of 63 students participated in this study. Participants were randomly assigned to a group of three people to complete a decision task. Compensations were given to the participants to increase the level of engagement. Participants were recruited through invitations or emails. All the experiment details are exempt from Institutional Review Board (IRB) review according to federal regulations. The exemption is determined by the Old Dominion University Engineering Human Subjects Review Committee (#1516719-6). The exemption letter can be found in Appendix A.

The background knowledge of the SODA process and the decision task of the participants are assumed to be comparable. In other words, all participants did not have any knowledge of SODA and the decision task prior to the study. The questionnaire was sent out with the invitation to assess the knowledge of SODA and the decision task. Only participants who did not have prior knowledge of SODA and the decision task were included in this experiment. Participants were randomly assigned into three independent groups. They were not aware of which groups they were assigned (i.e., blind experiment). A random assignment helps distribute the characteristics of the participants over the nature of the treatment, so the participants do not selectively bias the outcome. It also “helps to ensure that the error effects are statistically independent” (Kirk, 2013, p. 4).

All records were kept confidential to ensure the anonymity of the collected data. Only demographic data that were collected are age, gender, work experience, and level of education. The information was needed, for example, because age differences may affect the outcome of the study (Thornton & Dumke, 2005). Moreover, the same logic applies to the difference in the work experience and level of education. Following the data collection, the raw data was kept in a secured place, which is located in the department of Engineering Management and Systems Engineering, Old Dominion University. The raw data was also destroyed after the final submission of this dissertation.

Estimation of Sample Size

Power analysis is a tool that helps to determine the appropriate sample size for an experiment. Four parameters are concerned in a power analysis: alpha, beta, effect size, and sample size (Cohen & Cohen, 1983). In other words, the sample size for an experimental research design can be calculated if the other three variables are fixed. However, some researchers apply a "rule of thumb" to calculate a sample size for a study. For example, Ho (2014) states that at least 20 times more observations than a number of the independent variable would be a fair start. There were three conditions in this present study which, according to Ho (2014), would require 60 observations (20 per condition) to start.

The sample size is proportionally related to three other factors: the level of statistical significance (α), amount of power design $(1 - \beta)$, and effect size. Alpha (α) was set at 95% confidence – 0.05 probability of Type I error (the probability of rejecting the null hypothesis when it is true). The level of significance is set by convention in social science research (Hair, Black, Babin, & Anderson, 2014). Beta (β) represents the probability of not rejecting the null hypothesis when it is not true – Type II error. Power is a probability of correctly rejecting the null hypothesis when it is not true (1 – β) (Hair et al., 2014). Field (2009) also defines power as a probability of detecting an effect of the experiment if it existed. Cohen (1988, 1992); Cohen and Cohen (1983) suggest that 0.2 is an acceptable probability of a Type II error. Therefore, the power was set at 1 – β = 1 – 0.2 = 0.8 (i.e., 80% chance of detecting an effect of the experiment if it exists) (Field, 2009).

The effect size indicates whether the differences in the means of the groups are statistically significant (Sharma, 1996). An effect size is also considered as a "number, one free from our original measurement unit, with which to index what can be alternately called the degree of departure from the null hypothesis of the alternative hypothesis" (Cohen, 1988, p. 20). In other words, the effect size is a standardized measurement that quantifies the size of the difference between groups in an experiment (Fan & Konold, 2010). Hair et al. (2014) argue that effect size indicates whether the observed relationship – either difference or correlation – is meaningful. Ho (2014) also notes that the effect size is proportionally related to the sample size. There are many types of the effect size which are reported in the literature, e.g., Cohen's d, Pearson's correlation coefficient I, and Eta squared (Field, 2009).

At the design stage, the effect size can be predicted from the previous study. Wu et al. (2016) report the large effect size (Cohen's d = 0.82) in an experiment where, there is a statistically difference between a PSM approach and verbal-text groups (mean difference = 0.16, t = 2.89, df = 49, p<0.05). Given the similarity of the two studies, the effect size in this study should be estimated as observed in Wu et al. (2016). The fact that effect size is a standardized measurement, Borenstein et al. (2009) provide the conversion equation (as cited in Magpili-Smith, 2017) below:

$$d = \frac{2r}{\sqrt{1 - r^2}} \qquad \text{(Eq. 1)}$$

The result of the conversion (from d = 0.82 to r) is r = 0.3794, therefore, the eta square (R^2) is 0.1439. Cohen (1988) notes the relationship between eta square and f value as in the following equation:

$$f = \sqrt{\frac{\eta^2}{1 - \eta^2}} \qquad \text{(Eq. 2)}$$

Therefore, the estimated effect size f in this study is 0.41. According to the power table, the sample size n for each condition is estimated to be 21 observations per group with effect size f equals 0.40, power equals 80, and alpha at 0.05 (Cohen, 1988, p. 313). Thus, the estimated sample size of this current study is 63. The same output is also derived from the G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007), as shown in Figure 4.

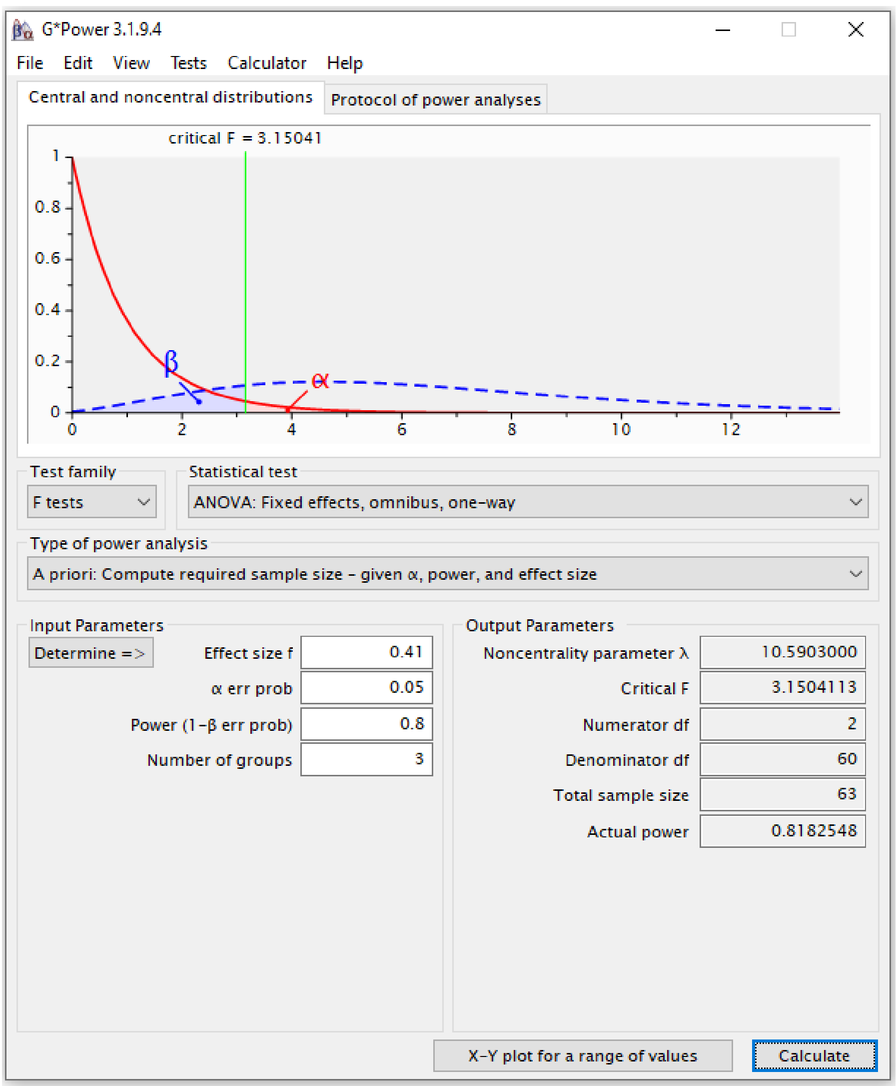

Figure 4. G*power Output

Therefore, from Figure 4, the minimum sample size of this study was calculated to be 63 samples (21 samples per condition).

Group Formation

Participants were randomly assigned to a three-persons group. This experiment was conducted in a small group environment. In this current study, all three members of the group received the same case background – the discussion of the exercise will be elaborated later. However, each member will receive a different piece of information to solve the problem. These pieces of information are extracted from the collective information, as shown in Figure 5. The purpose of the group formulation is to simulate a messy situation. A mess simulation in this experiment is based on Pidd's definition of a mess: "A mess is a system of problems with multiple stakeholders who may hold quite different views of what feasible and desireable (Pidd, 2009, p. 46)."

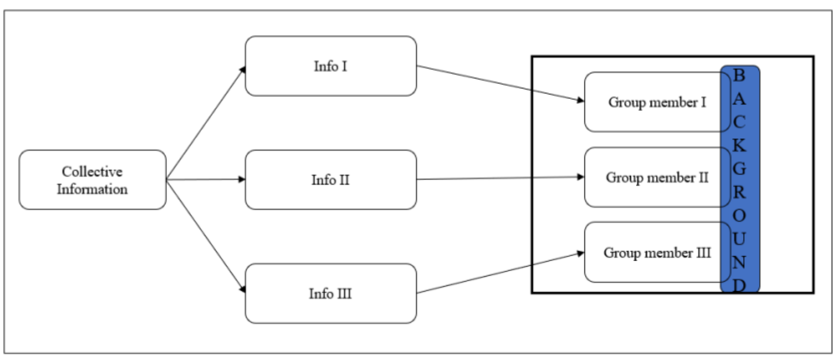

Figure 5. Group Formation

As shown in Figure 6, participants were randomly assigned to three different decision-making conditions (control and treatment groups). Prior to the experiment, participants were asked if they were aware of the Winter Survival Exercise (WSE) or SODA. This is to mitigate the possibility of confounding factors. It is to make sure that the intended manipulation caused changes in the dependent variable. Participants who were aware of any of the mentioned aspects were excluded from the study.

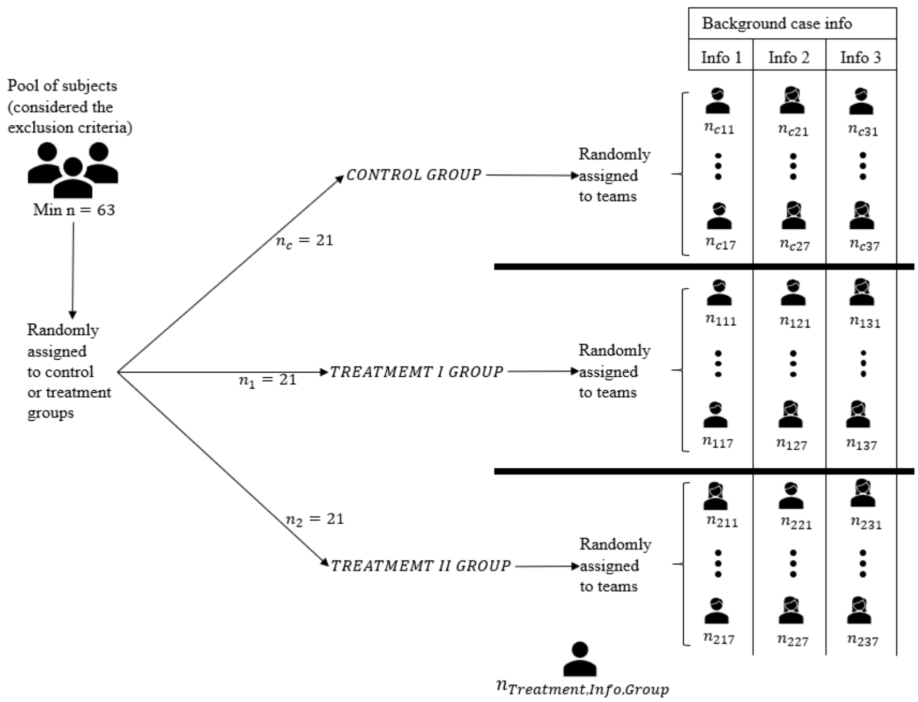

Figure 6. Randomization of Samples

Experimental Conditions

It should be noted that there were facilitations (one facilitator with a predesigned script) in all three conditions. The only difference between the three groups is the method used during the discussion.

Control (Group discussion)

After forming a group, the differing pieces of information were provided to the participants. With the facilitator, all the members were asked to discuss and complete the decision task. Given that each member possesses a different piece of information, it was expected that a group-discussion session would provide a bigger picture to the group. Working as a group in a decision task has been argued to be superior to working as an individual (Stapleton, 2007; Yetton & Bottger, 1982). For each group member, the problem-solving confidence was assessed after the completion of the tasks, as shown in Figure 7.

Figure 7. Control Group

Treatment I (SODA I process)

The principle of SODA was applied as a treatment in this study. After forming a group, a treatment I was applied, as shown in Figure 8. The cognitive map I, II, and III were provided to participants as part of the SODA process. All cognitive maps are created based on Info I, II, and III, as shown in Figure 5, respectively. In other word, the information in the cognitive maps are identical to the infos. They are only presented differently. After participants comprehended the given information (3-5 minutes), the predesigned merged map was provided to this group. The predesigned merged map was constructed based on the information from the individual map I – III (i.e., the collective information shown in Figure 5). It is argued that the facilitator should involve in the creation of the merged map in SODA I process (Pidd, 2009). The emphasis of the facilitator's contribution to the creation of a merged map in a SODA process is also discussed in Westcombe (2002a).

After providing the merged map, the facilitator used a predesigned script to explain the rationale behind the construction of the map. This predesigned script does not reveal any of the insights associated with the decision task (as shown in Appendix E). It only covers the construction of the merged map in general, as elaborated in Ackermann and Eden (2001); Eden (1989); Eden et al. (1992). Participants can modify the map where they find appropriate. After that, a group was asked to discuss and complete the task using the given merged map.

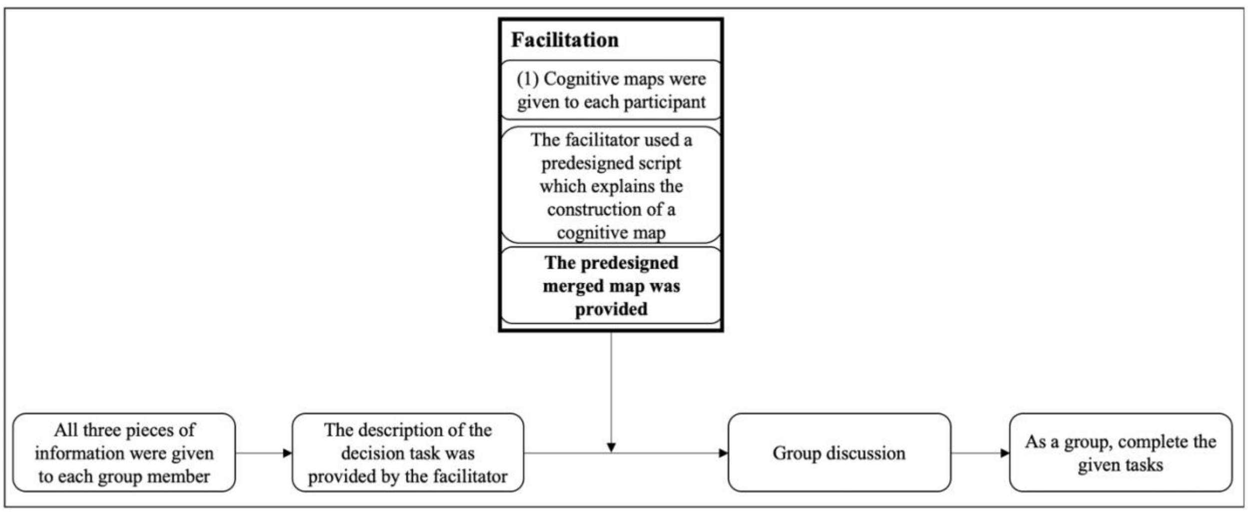

Figure 8. Treatment I

Figure 8 indicates the process of treatment I. For each group member, the problem-solving confidence was assessed after the completion of the tasks.

Treatment II (SODA II Process)

Identical to treatment I, after forming the group, treatment II was applied, as shown in Figure 9. Instead of providing participants the merged map, this group was asked to construct the merged map based on the information from each individual map (map I – III). The facilitator used the same predesigned script to explain the construction of the merged map. Again, this predesigned script does not reveal any of the insights associated with the exercise. It will only cover the construction of the merged map in general, as elaborated in Ackermann and Eden (2001); Eden (1989); Eden et al. (1992). After that, a group will discuss and complete the tasks using the merged map.

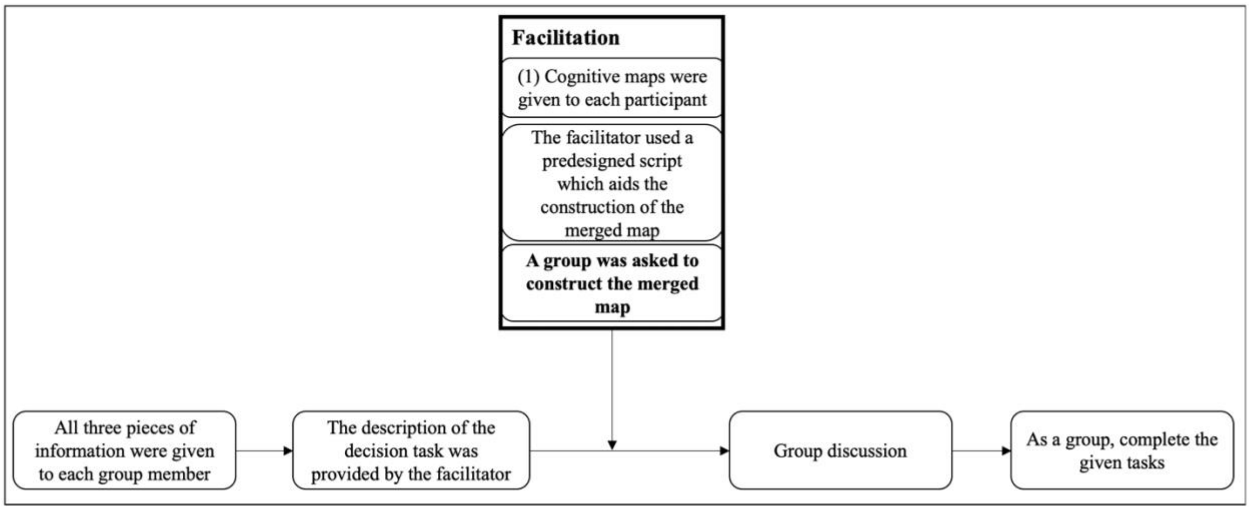

Figure 9. Treatment II

Figure 9 indicates the process of treatment II of this research. For each group member, the problem-solving confidence was assessed after the completion of the tasks.

Procedure

The data collection was between 20 minutes to 1 hour per session. The time was dependent on group decision-making speed and the time it takes to respond to the questionnaire. The procedure in the treatment group is aligned with the analysis of SODA process in Sørensen and Vidal (2008). The analysis is based on the principles of interactive planning: Participation, Co-ordination, Integration, and Continuity. SODA is applicable when each individual in a group perceives the world subjectively. Also, the organization is made up of the processes and negotiations more than structures. Lastly, the analyst’s role is a facilitator who helps the group to reach a decision by using cognitive maps as the primary tool.

General Procedure

1. The data collection was face-to-face with the participants. Names of the participants were not recorded as part of data collection.
2. The data collection procedures are outlined in the following steps:
    a. Participants were contacted via invitation or email to set up a meeting time.
    b. According to the availability, participants were randomly assigned to a group of three. Each group was randomly assigned to a decision-making condition.
    c. After arrival at the experiment site, participants were given a notification statement, shown in Appendix B.
    d. The facilitator greeted participants and explained the purpose of the study using a notification statement.
    e. The facilitator provided a case background and different pieces of information to each participant. All participants in a group were not aware that they possessed different pieces of information.
    f. Based on the decision-making condition of a group, participants were asked to complete the task as a group (see next section for different decision-making conditions).
    g. After completing the task as a group, participants were asked to complete a problem-solving confidence survey, as shown in Appendix D.
    h. The facilitator thanked the participants for their contributions to the study.

Different decision-making conditions procedures

1. Control (Group discussion)
    a. Participants were given approximately 5 minutes to comprehend the given information.
    b. The facilitator asked participants to discuss and complete the task as a group.
2. Treatment I (SODA I process)
    a. The facilitator provided cognitive maps according to the unique information. Each map was generated from the unique piece of information that each member possessed.
    b. Participants were given approximately 5 minutes to comprehend the information from a cognitive map
    c. The facilitator presented the predesigned merged map to a group
    d. The facilitator used the predesigned script to explain the rationale and the construction of the predesigned merged map
    e. Participants were asked to complete the task as a group using the predesigned merged map. They were allowed to modified the merged map if they found necessary.
3. Treatment II (SODA II process)
    a. The facilitator provided cognitive maps according to the unique information. Each map was generated from the unique piece of information that each member possessed.
    b. Participants were given approximately 5 minutes to comprehend the information from a cognitive map.

c. The facilitator asked a group to construct the merged map.

d. The facilitator used the predesigned script to explain the rationale and the construction of the merged map. (It should be noted that, as elaborated earlier, this predesigned script does not reveal any of the insights associated with the exercise/task. It will only cover the construction of the merged map in general.)

e. Participants were asked to complete the task as a group using the merged map.

Analytical Strategy

The objective of this study is to investigate if there is a difference among the decision-making conditions (control, treatment I, and treatment II groups). Analysis of Variance (ANOVA) was used to compare the overall means among groups. ANOVA only provides the conclusion that there is the overall means difference among groups, not a specific comparison. Given the hypotheses of this experiment, there was a need for further analysis to find out the magnitude of the mean differences (i.e., Control VS SODAs, Control VS SODA I, Control VS SODA II, and SODA I VS SODA II). The selected follow-up analysis, after a positive ANOVA result, is planned comparisons or planned contrasts (Field, 2009). All calculations were done using the Statistical Package for the Social Sciences (SPSS) software.

Analytical tools

The objective of this research is to reject the null hypotheses that were elaborated earlier. One of the ways to achieve the goal is to test the equality of the means scores among groups. In other words, to indicate that the means from the control and treatment groups are significantly different. Analysis of Variance (ANOVA) is one of the statistical methods that compare the means among different groups (Bray, Maxwell, & Maxwell, 1985). It is applied when there is an interest in the overall mean differences from two or more independent groups (Ho, 2014). ANOVA is analyzed based on the F-ratio. Field (2009) explains the F-ratio as a “measure of the ratio of the variation explained by the model and the variation explained by systematic factors” (p.258). Some researchers indicate that ANOVA analyzes the variation among and within the groups (Berenson, Levine, & Krehbiel, 2006).

There are two assumptions that need to be reached when apply ANOVA. The dependent variable is normally distributed – *Normality*. Normality can be tested by the Shpiro-Wilk, normal Q-Q plot, the detrended Q-Q plot, and the z test for the skewness of the data (Ho, 2014). Also, all the groups have approximately equal variance on the dependent variable – *Homogeneity of variance*. The homogeneity of variance can be evaluated by Levene’s test. It is worth noting that F-statistic can be robust to violations of these assumptions when the group sizes are equal (Field, 2009).

In terms of the assumption of the normality of the data, ANOVA is considered a robust test against normality assumption (Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017). Field (2009) states that the normality of the data, when group sizes are equal, has a small effect on the F-test – “the power of F also appears to be relatively unaffected by non-normality” (p.360). However, F-test can be biased if the group sizes are small and unequal. Moreover, Budescu (1982) and Budescu & Appelbaum (1981) find that the heterogeneity of variance also has a small effect on the F-test, and “trying to stabilize variances does not substantially improve power” (as cited in Field, 2009, p. 360). Again, under the assumption that the sample sizes are equal. ANOVA is considered one of the most robust statistical tools in educational and social science research.

As mentioned earlier, ANOVA only gives one overall test of the equality of means among the groups of samples. A significant result from ANOVA indicates that the manipulation of the independent variable has a significant effect on the dependent variable. In other words, the significant result shows that the means among the groups differ significantly (Ho, 2014). However, the result does not identify where the difference is nor the magnitude of the difference. The follow-up techniques will be needed to obtain the location and magnitude of the differences.

Following a significant result from one-way ANOVA, Field (2009) argues that additional analysis is needed to find out which groups differ – the location and magnitudes of the differences. Planned contrasts and post hoc tests are widely used for follow-up purposes. Planned contrasts analysis focuses on specific comparisons between group means. The analysis compares group means based on research hypotheses. There are two forms of planned contrasts: pairwise and complex comparisons. A pairwise comparison focuses on the difference between two means, while a complex comparison involves an average of group means (Keppel & Wickens, 2004).

Another follow-up approach, after a significant result from ANOVA, is a post hoc test. A post hoc test is more an exploratory approach. It explores the data for any difference means that exist (Field, 2009). Post hoc tests are used when there may be an emerged relevant comparison after the designed experiment (Keppel & Wickens, 2004). The concept is different from the planned contrast approach, which targets specific comparisons. The post hoc techniques consist of "pairwise comparisons that are designed to compare all different combinations of the treatment groups" (Field, 2009, p. 372). Bonferroni's and Tukey's tests are considered to have a reasonable control regarding the Type I error rate. Both techniques perform well when group sizes are equal. However, Hochberg's GT2 and Gabriel's pairwise test procedure will work with unequal group sizes (Field, 2009).

According to the hypotheses in this study, the planned contrast was more appropriate to determine the focusing results. Both pairwise and complex comparisons were applied.

Validity

Internal validity is concerned with the causal relationships between an independent variable and a dependent variable. In other words, it is concerned with whether the experiment is being properly controlled to mitigate the effect of confounding factors on the research outcome. Four controlled variables were discussed to indicate a high level of internal validity in this experiment. For example, based on a literature review, there is a heavy emphasis on a facilitator role in the SODA process. It might pose a threat to the validity of this study. This threat was addressed by using the predesigned script, which was used by one facilitator. Secondly, there may be a chance that a participant has a certain knowledge prior to the experiment (e.g., been exposed to the process of SODA and WSE) that may impact the outcome of the research. The previous experience of exposure to a similar decision-making method (e.g., training and workshop) may affect the results. It is because the previous phenomenon can impact problem-solving confidence. As discussed in Boldt et al. (2019) that experience-based confidence affects future confidence. The exclusion criteria addressed this threat: only participants who have no experience in SODA and WSE prior to the experiment were included in the study. Therefore, it can be assumed that the differences in the dependent variable were caused by the intended manipulation of the independent variable.

CHAPTER 4

RESULTS

Background Information

Demographic information about the sample used in this current research and descriptive measures will be discussed in this section. As elaborated earlier, the initial design included 63 participants, 21 subjects for each experimental condition. Sixty-three individuals participated in the experiment. Within each group, participants did not have an extensive history of working together prior to this study. Each group was also randomly assigned to a decision-making condition, as presented earlier in Figure 6.

The background information was collected before the beginning of each experiment. The data collection includes the following variables: age, gender, work experience, education level, and major. Data concerning age reveals that 76% of the participants were within the range of 19-23 years old, and the remaining 24% were older than 24 years old. As far as gender demographics, the sample included 81% of males and 19% of females. Data regarding work experience indicated that 48% of the participants had 0-3 years of work experience, 28% had 3-5 years of work experience, and 24% of the participants had 5+ years of work experience. For the education level, 97% of participants were undergraduate students, with 3% of master's students. With respect to major, 95% of the participants were engineering students, and the remaining 5% from other fields.

Before each experiment, all participants were asked to complete an application form, which served as a filter. This form includes two questions regarding the exclusion criteria of the study: No knowledge of both the Strategic Options Development and Analysis (SODA) and the Winter

Survival Exercise. It is because the knowledge of both matters can potentially be confounding factors to the outcome of the study, as elaborated in the previous chapter.

The objective of this research is to assess problem-solving confidence in different decision-making conditions. Given that problem-solving confidence is a subjective measure, there is a need to assess the participants' level of problem-solving confidence in general. Item number five in a survey was used to assess the general problem-solving confidence of the participants.

	Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	*Strongly Disagree*
Many problems I face are too complex for me to solve.	1	2	3	4	5	6

Figure 10. Statement Assessing General Problem-Solving Confidence

As shown in Figure 10, to respond "Strongly Agree" to this item can be implied that an individual has a low level of confidence regarding problem-solving. On the other hand, to respond as "Strongly Disagree" to this item can be implied that an individual has a high level of confidence regarding problem-solving. As presented in Figure 11, results revealed that 3% agreed, 6% slightly agreed, 22% slightly disagree, 62% disagreed, and 7% strongly disagreed with the statement shown in Figure 10. It can be concluded that 91% of participants have a similar level of problem-solving confidence (participants who responded range from "Slightly disagree" to "Strongly disagree"). The results ensure that participants had similar levels of problem-solving confidence prior to the experiment, and the final confidence level can be logically compared.

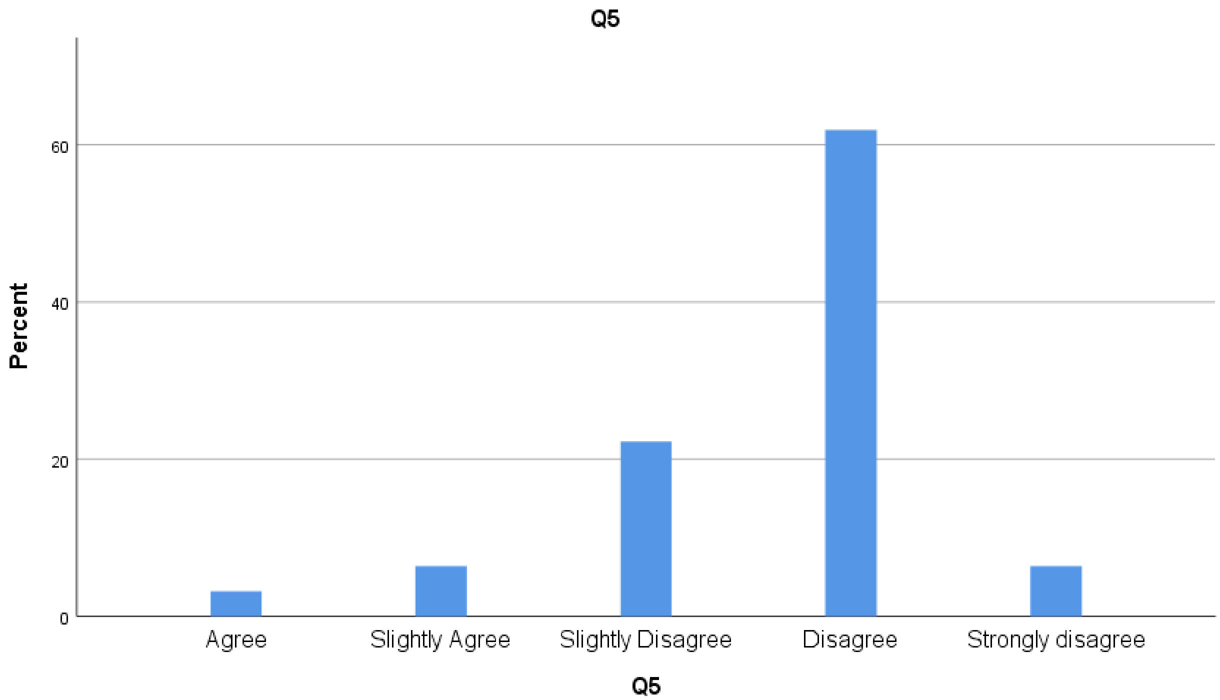

Figure 11. Percentage of General Problem-Solving Confidence

Statistical Analysis

The main purpose of this research is to show the value of a Problem Structuring Method (PSM), specifically Strategic Options Development and Analysis (SODA), as an effective decision tool in a messy problem. This experiment has a different decision-making condition as an independent variable. There were three decision conditions: control, SODA I, and SODA II groups. Furthermore, the problem-solving confidence was assessed as a dependent. This research aims to investigate if there is any difference among overall group means. The differences among groups show the impact of SODA in this experiment. Analysis of Variance (ANOVA) was used to evaluate whether the difference among groups is statistically significant. The analysis was conducted using SPSS software.

Evaluation of Assumptions

The normality of the data was explored using the Kolmogorov-Smirnov test and the Shapiro-Wilk test. If the test is non-significant ($p > 0.05$), it can be concluded that the data is normally distributed. On the other hand, if the test is significant ($p < 0.05$), the data is non-normal (Field, 2009). Table 7 indicates the normality test of the data. Field (2009) states that ANOVA can be robust to violations of normality when group sizes are equal. Given that the deviation of normality based on the Shapiro-Wilk test in the control group is very small, and the group sizes are equal, it can be assumed that the violation has little impact on the outcome of ANOVA in this study. Q-Q plot for the control group also indicates that the deviations from normality are not very significant, as shown in Figure 12. Both data from treatment groups are normally distributed, as shown in Table 7. The Q-Q plots for the treatment groups are displayed in Figure 13 and Figure 14, respectively.

Table 7. Tests of Normality

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Confidence_Scores	Control	.242	21	.002	.886	21	.019
	SODA I	.134	21	.200*	.962	21	.567
	SODA II	.116	21	.200*	.951	21	.359

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

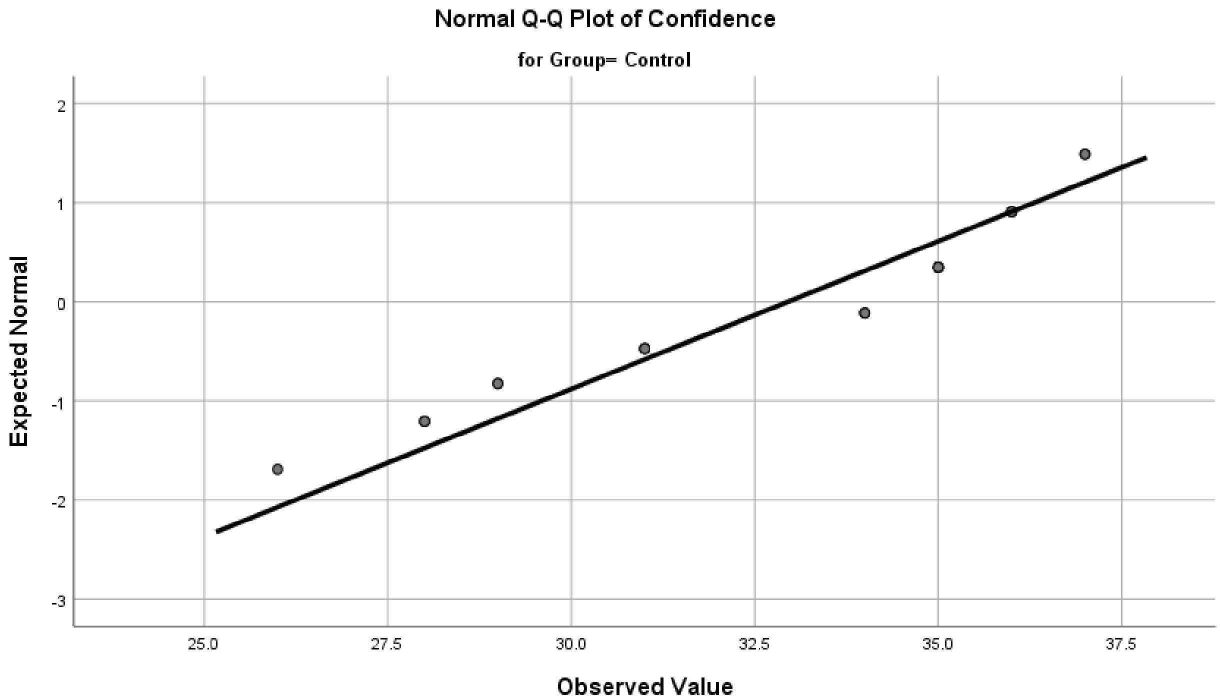

Figure 12. Normal Q-Q Plot for Control group

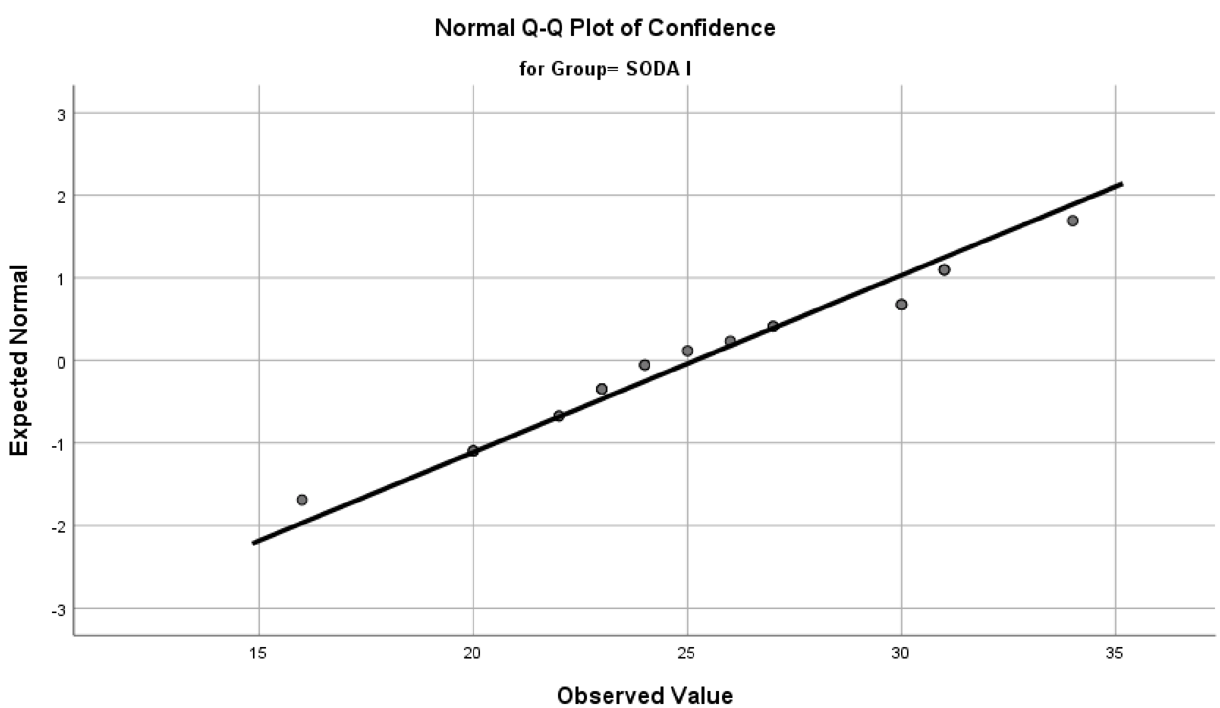

Figure 13. Normal Q-Q Plot for Treatment I group

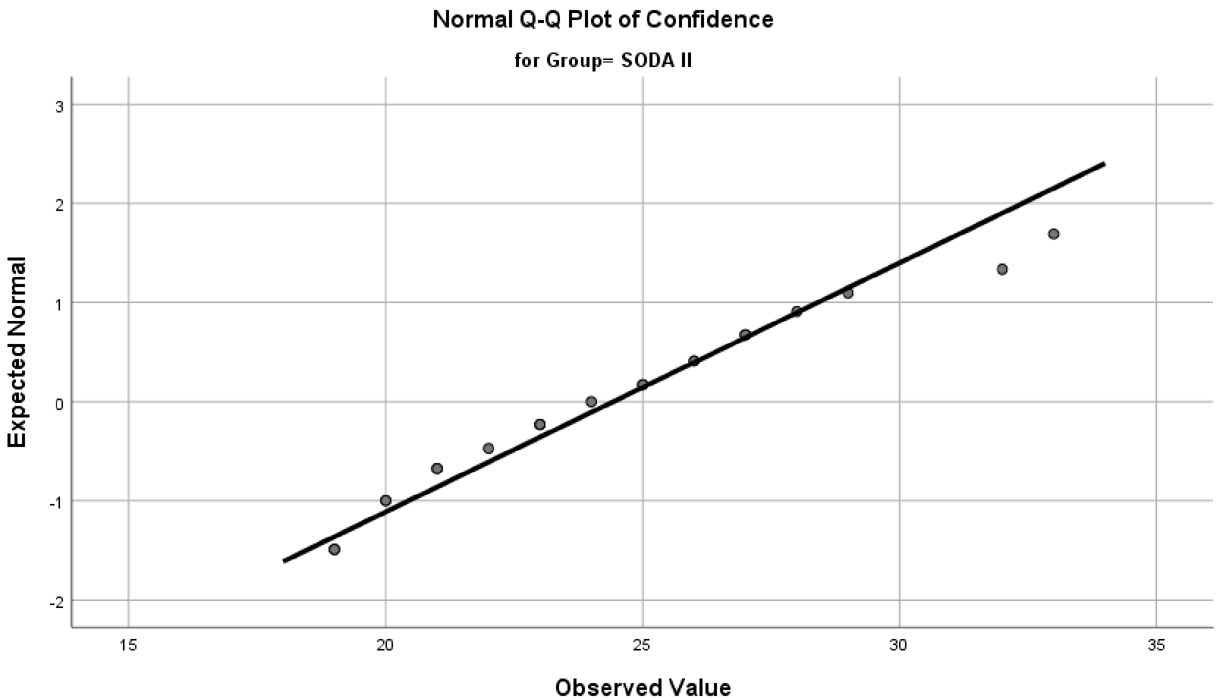

Figure 14. Normal Q-Q Plot for Treatment II group

The homogeneity of variance was assessed using the Levene's test. This test assesses whether the variances in different groups are equal. If the test is significant ($p < 0.05$), it can be concluded that the variances are significantly different. In other words, the assumption of homogeneity of variance has been violated. The assumption is tenable if Levene's test is non-significant ($p > 0.05$) (Field, 2009). In this current study, homogeneity of variance of the problem-solving confidence across the groups can be assumed, as shown in Table 8.

Table 8. Levene's Test of Equality of Variances of the Problem-Solving Confidence

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Confidence_Scores	Based on Mean	1.020	2	60	.367

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: Confidence

b. Design: Intercept + Group

Results of the Hypothesis Tests

Four hypotheses were tested in this research. First, a hypothesis related to overall means between the two decision-making conditions – control (regular group discussion) and treatment groups (SODA). Second, a hypothesis related to the overall means between a control group (regular group discussion) and a treatment I group (SODA I). Third, a hypothesis related to the overall means between a control group (regular group discussion) and a treatment II group (SODA II). Finally, a hypothesis related to the difference between SODA I and SODA II groups.

The dependent variable in this experiment is problem-solving confidence. This variable is measured after the participants solve a hypothetical question. The problem-solving confidence was assessed by the validated questionnaires as elaborated earlier (shown in Appendix D). The interpretation of the PSI scores was elaborated in the previous chapter. The lower scores reflect a high level of problem-solving confidence. The results of the hypothesis tests are provided in the following sections.

ANOVA is applied in this research to assess the overall means difference between groups. Table 9 indicates the descriptive statistics of the groups. Following, Table 10 presents the ANOVA results, revealing that the difference among three independent groups was statistically significant, $F(2, 60) = 28.682$, $p < 0.001$, Eta squared = 0.489. Figure 15 and Figure 16 are mean plots and a boxplot of PSI scores, respectively. It should be noted that low scores from PSI indicate a high level of confidence.

Table 9. Descriptive Statistics of the Groups

Descriptives

Confidence_Scores

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	21	32.95	3.354	.732	31.43	34.48	26	37
SODA I	21	25.19	4.665	1.018	23.07	27.31	16	34
SODA II	21	24.43	3.982	.869	22.62	26.24	19	33
Total	63	27.52	5.553	.700	26.13	28.92	16	37

Table 10. Results from the Analysis of Variance

ANOVA

Dependent Variable: Confidence_Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	934.381[a]	2	467.190	28.682	.000	.489	57.363	1.000
Intercept	47726.286	1	47726.286	2929.990	.000	.980	2929.990	1.000
Group	934.381	2	467.190	28.682	.000	.489	57.363	1.000
Error	977.333	60	16.289					
Total	49638.000	63						
Corrected Total	1911.714	62						

a. R Squared = .489 (Adjusted R Squared = .472)

b. Computed using alpha = .05

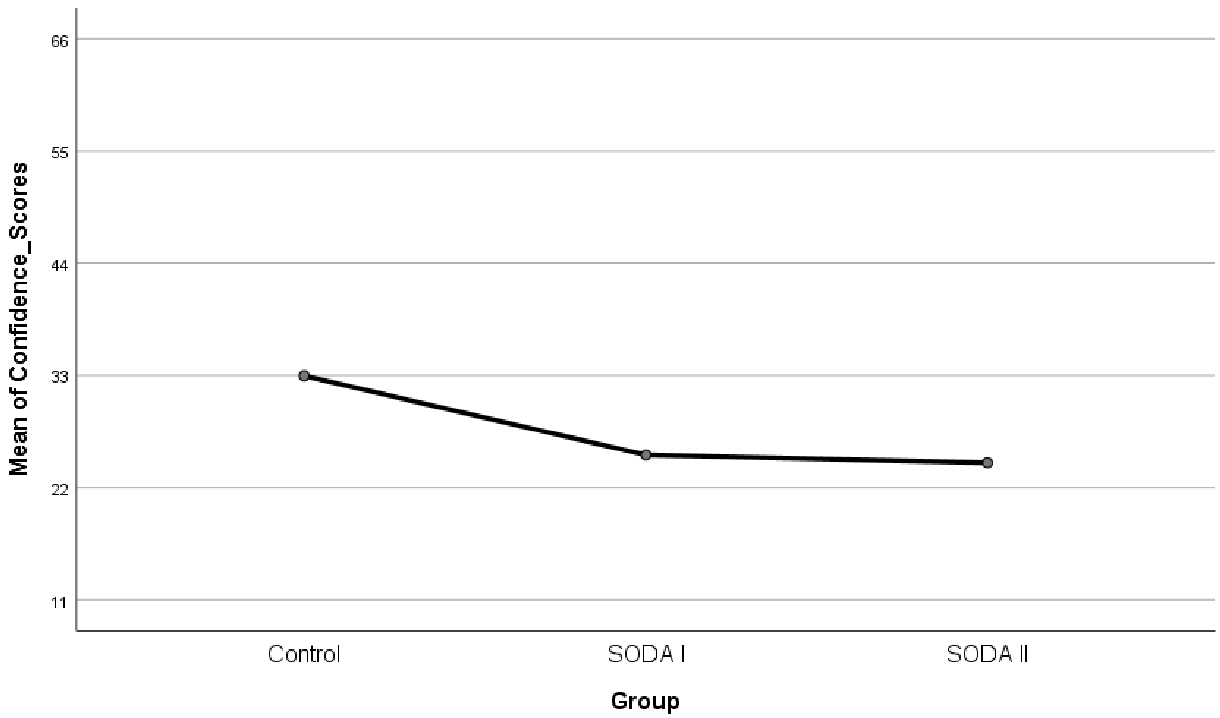

Figure 15. PSI Scores Means Plot Among Groups

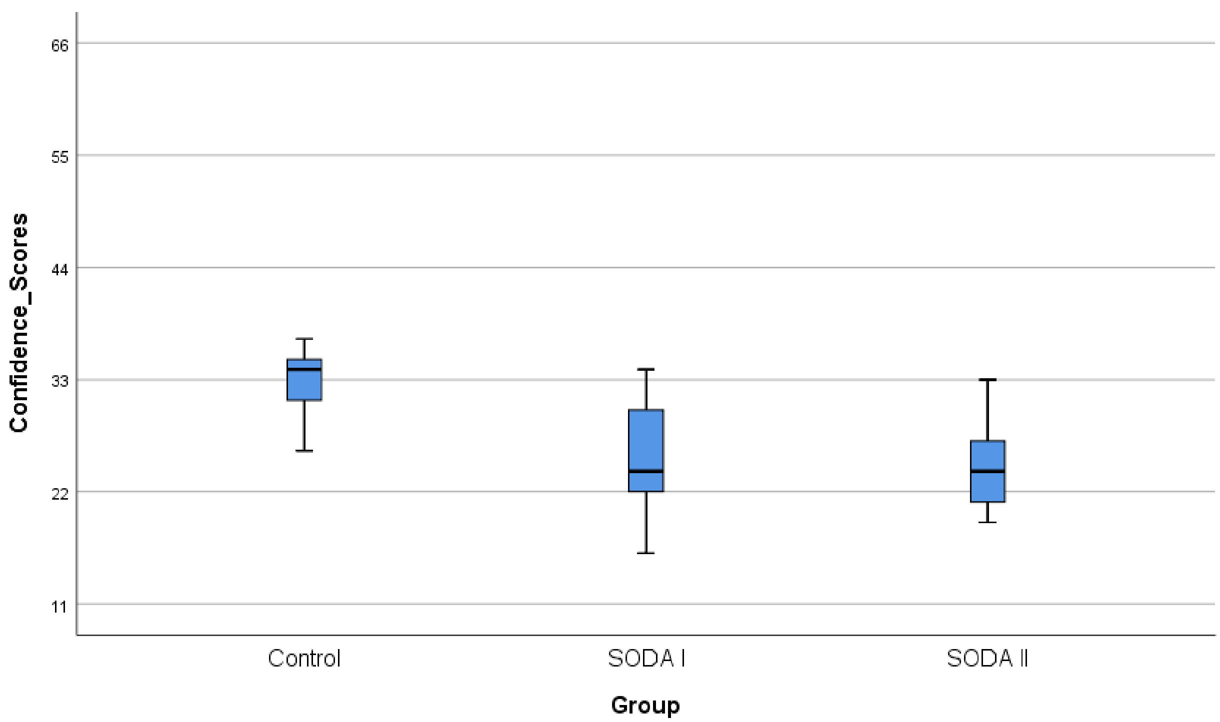

Figure 16. Boxplot of PSI Scores by Groups

ANOVA result only provides the information that one or more of the differences between group means is statistically significant. It does not provide the information on where the difference between groups occurs or which groups are different. The generality of the results is inefficient to study specific effects (Keppel & Wickens, 2004). The magnitude of the differences between the groups will be elaborated in the following sections.

Hypothesis 1

As discussed earlier, most of the reports on the evaluation of problem structuring methods are anecdotal. Therefore, the first hypothesis compares the overall means between the control group and SODA groups. The comparison is conducted based on the concept of the planned contrast (Field, 2009; Keppel & Wickens, 2004). This hypothesis aims to explore whether SODA is better than a regular group meeting approach. The arguments of showing the benefit of problem structuring methods if the methods are better than a general group meeting were mentioned in the literature (Lami & Tavella, 2019; White, 2006). The null and the alternative forms of this hypothesis are:

H_{o1}: There is no difference in the problem-solving confidence between the group that uses the SODA process and the group that does not use the SODA process

H_{a1}: The average level of problem-solving confidence of the members in a group using SODA process will be different than when SODA process is used

As shown in Table 11 and Table 12, the results of the planned contrast analysis revealed that the main effect of SODA on problem-solving confidence between control and treatment groups was statistically significant, $t(60) = 7.549$, $p<0.001$ (2-tailed). Therefore, the null hypothesis can be rejected. The scores of the participants in a control group are higher than the scores of the participants in treatment groups. Figure 17 shows a boxplot of the comparison between the control group and SODA groups. According to the interpretation of PSI, participants in SODA groups show a higher level of problem-solving confidence than the participants in the control group.

Table 11. Contrast Coefficients for Planned Contrast Analysis

Contrast Coefficients

	Group		
Contrast	Control	SODA I	SODA II
1	1	-.5	-.5

As elaborated earlier, to test the hypothesis, the planned contrast analysis was performed. The only constraint on a planned contrast analysis is the contrast coefficients sum to zero (Keppel & Wickens, 2004). The different signs of the coefficients reflect the direction of the difference. Field (2009) explains that the “groups coded with positive weights will be compared against groups coded with negative weight” (p.365). As presented in Table 11, the focus is on the pairwise comparison between the control group (positive sign) and the SODA I and SODA II groups (negative sign). In other words, this contrast focuses on the difference between the control group and the two treatment groups.

Table 12. Contrast Test

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Confidence_Scores	Assume equal variances	1	8.14	1.079	7.549	60	.000

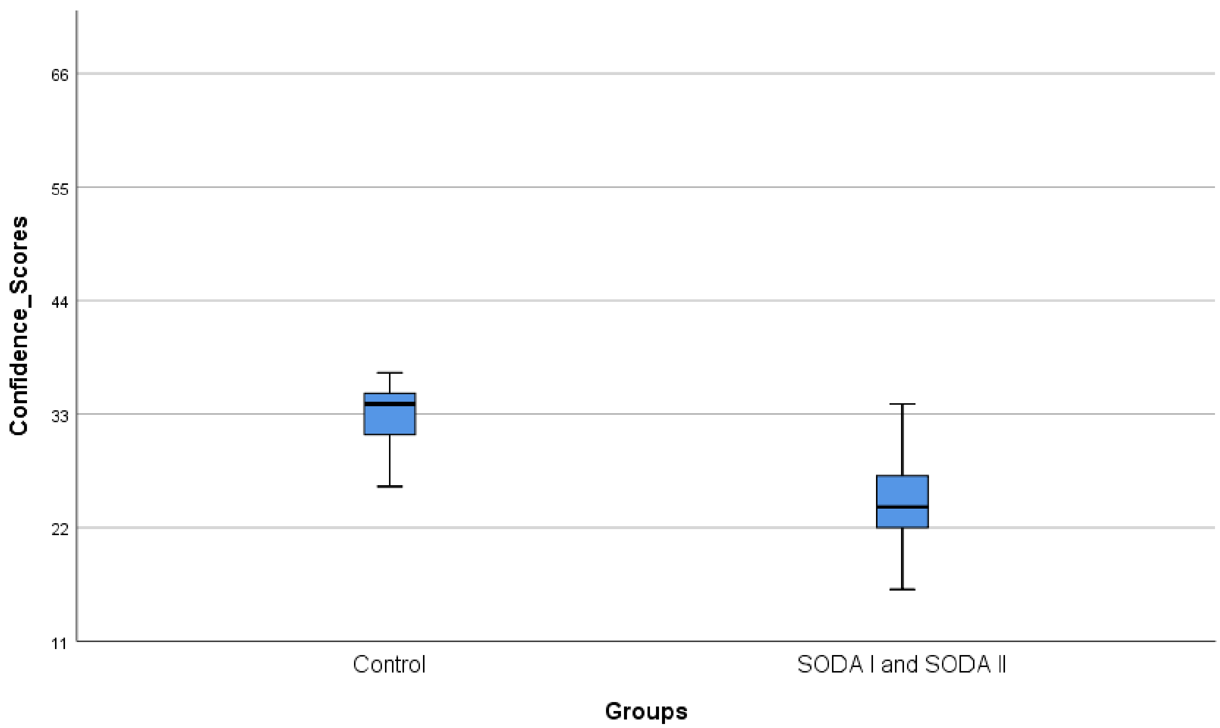

Figure 17. Boxplot of PSI Scores by Groups

It can be concluded that a group using the SODA shows a higher level of problem-solving confidence than the group that did not use SODA. One of the possible reasons for reaching this conclusion is a level of ownership of the output of the process. Horlick-Jones et al. (2001) indicate that a higher level of ownership of the output is present after a PSM intervention. Franco (2007) similarly reports that PSM intervention creates strong ownership of the problem formulation among decision-makers. Another reason could be that the high level of shared understanding is reached among stakeholders in a group. The same argument can be found in McKay and Marshall (2005), who report shared understanding among stakeholders in a group with PSM intervention. In conclusion, the ownership of a decision and a higher level of shared understanding could lead to higher confidence shown in this experiment.

Hypothesis 2

This hypothesis compares the overall means between the control group and the group using the SODA I process. As elaborated earlier, there are two types of SODA interventions. Within a SODA I process, a merged map could be provided by the facilitator (Pidd, 2009). The merged map (i.e., strategic map) is used as a tool to generate discussions and negotiation among group members. The objective of this hypothsis is that there is little to no attempt to explore the effectiveness of each type of SODA intervention. This hypothesis aims to explore whether a group with SODA I process shows higher problem-solving confidence than a group without the SODA process. The null and the alternative form are:

> H_{o2}: There is no difference in the problem-solving confidence between the group that uses the SODA I process and the group that does not use the SODA process
>
> H_{a2}: The average level of problem-solving confidence of the members in a group using SODA I process will be different than when SODA process is used

As shown in Table 13 and Table 14, the results of the planned contrast analysis revealed that the main effect of SODA I process on problem-solving confidence between control and the treatment group was statistically significant, t(60) = 6.232, p<0.001 (2-tailed). Therefore, the null hypothesis can be rejected. The scores of the participants in a control group are higher than the scores of the participants in the SODA I group. Figure shows a boxplot of the PSI scores comparison between the control group and the SODA I group. According to the interpretation of PSI, participants in the SODA I group show a higher level of problem-solving confidence than the participants in the control group.

Table 13. Contrast Coefficients for Planned Contrast Analysis

Contrast Coefficients

	Group		
Contrast	Control	SODA I	SODA II
1	1	-1	0

The only constraint on a planned contrast analysis is that the contrast coefficients must sum to zero (Keppel & Wickens, 2004). The different signs of the coefficients reflect the direction of the difference. Field (2009) explains that the "groups coded with positive weights will be compared against groups coded with negative weight" (p.365). Further, a group that is not involved in comparison will be assigned a weight of 0. As presented in Table 13, the focus is on the pairwise comparison between the control group (positive sign) and the SODA I group (negative sign). In other words, this contrast focuses on the difference between the control group and the SODA I group.

Table 14. Contrast Test

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Confidence_Scores	Assume equal variances	1	7.76	1.246	6.232	60	.000

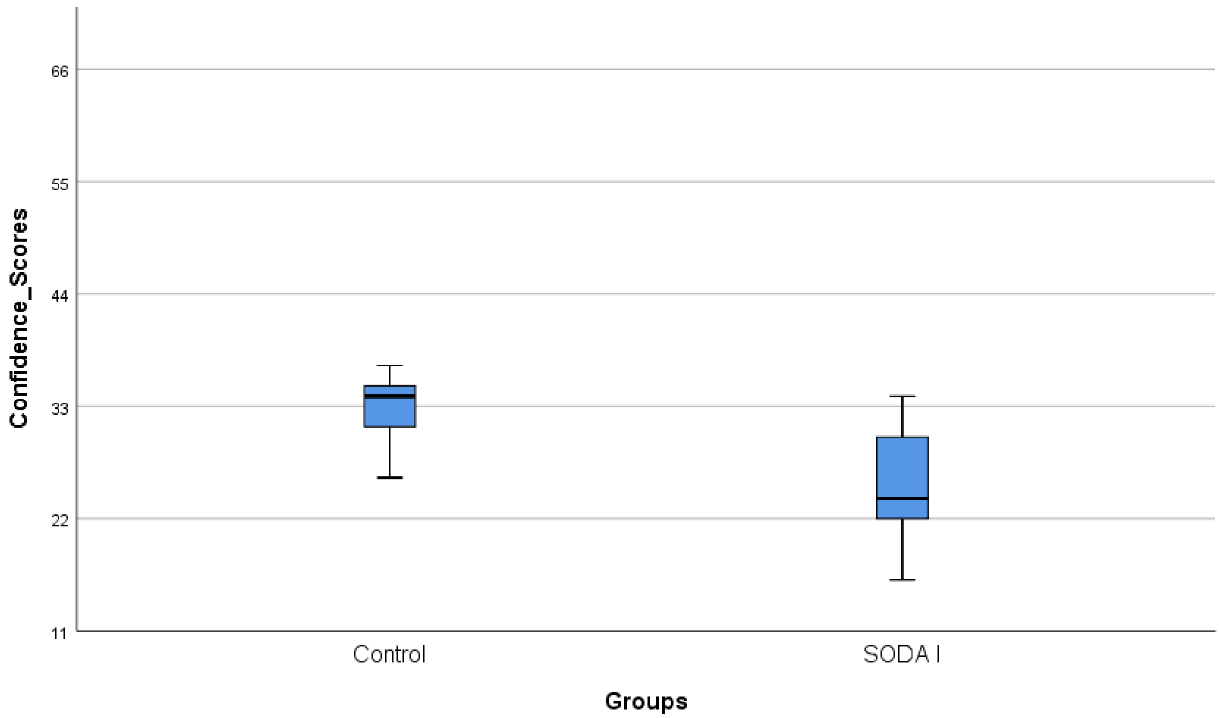

Figure 18. Boxplot of PSI Scores by Groups

Hypothesis 3

This hypothesis compares the overall means between the control group and the group using the SODA II process. As discussed earlier, there are two types of SODA interventions. Within a SODA II process, a merged map could be created by the group (Pidd, 2009). The merged map (i.e., strategic map) is used as a tool to generate discussions and negotiation among group members. There is little to no attempt to explore the effectiveness of each type of SODA intervention. This hypothesis aims to explore whether a group with the SODA II process shows higher problem-solving confidence than a group without the SODA process. The null and the alternative form are:

H_{o3}: There is no difference in the problem-solving confidence between the group that uses the SODA II process and the group that does not use the SODA process

H_{a3}: The average level of problem-solving confidence of the members in a group using SODA II process will be different than when SODA process is used

As shown in Table 15 and Table 16, the results of the planned contrast analysis revealed that the main effect of the SODA II process on problem-solving confidence between control and treatment group was statistically significant, t(60) = 6.844, p<0.001 (2-tailed). Therefore, the null hypothesis can be rejected. The scores of the participants in a control group are higher than the scores of the participants in the SODA II group. Figure 19 shows a boxplot of PSI scores comparison between the control group and the SODA II group. According to the interpretation of PSI, participants in the SODA II group show a higher level of problem-solving confidence than the participants in the control group.

Table 15. Contrast Coefficients for Planned Contrast Analysis

Contrast Coefficients

	Group		
Contrast	Control	SODA I	SODA II
1	1	0	-1

The different signs of the coefficients reflect the direction of the difference (Keppel & Wickens, 2004). Field (2009) explains that the "groups coded with positive weights will be compared against groups coded with negative weight" (p.365). Further, a group that is not involved in comparison will be assigned a weight of 0. As presented in Table 15, the focus is on the pairwise comparison between the control group (positive sign) and the SODA II group (negative sign). This contrast focuses on the difference between the control group and the SODA II group.

Table 16. Contrast Test

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Confidence_Scores	Assume equal variances	1	8.52	1.246	6.844	60	.000

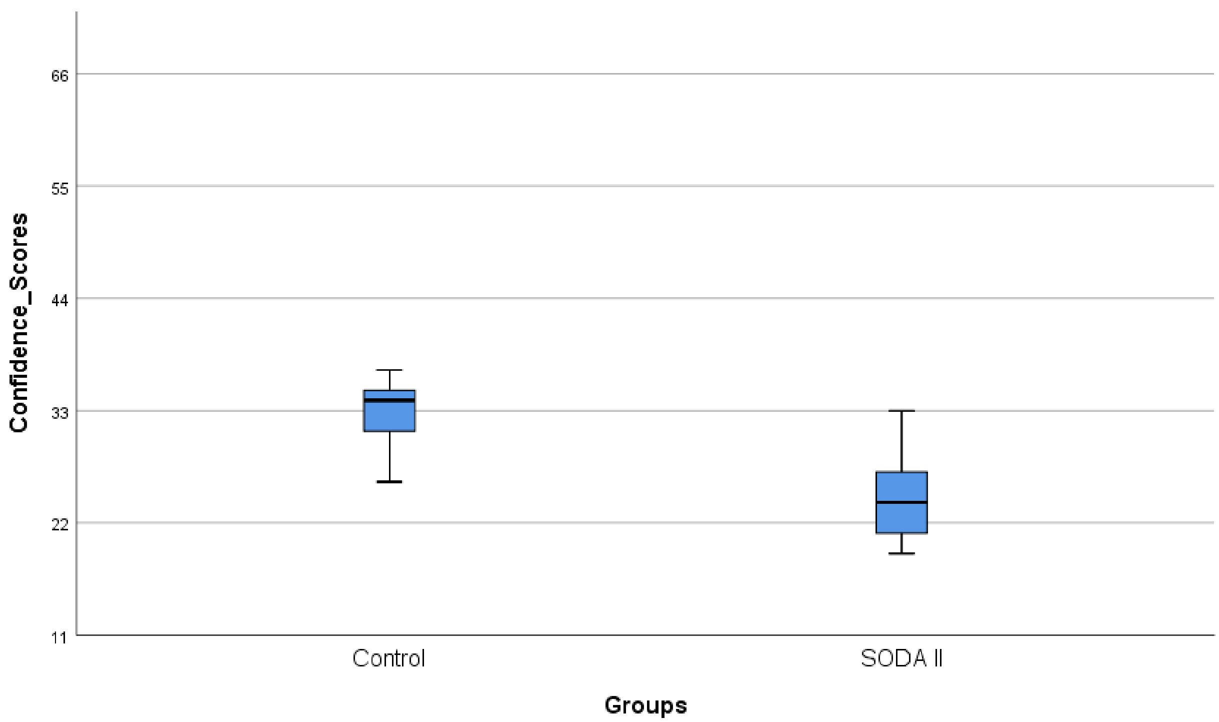

Figure 19. Boxplot of PSI Scores by Groups

Hypothesis 4

This hypothesis compares the overall means between the group using the SODA I process and the group using the SODA II process. As elaborated throughout this document, there are two types of SODA interventions (Pidd, 2009). There is little to no attempt to explore the differences between SODA interventions. The notion of comparing the effectiveness among PSM is also mentioned in the literature (Midgley et al., 2013; White, 2006). The fourth hypothesis of this study aims to explore whether there is a difference in problem-solving confidence between a group with the SODA I process and a group with the SODA II process. The null and the alternative form are:

> H_{o4}: There is no difference in problem-solving confidence of the members between a group using the SODA I process and a group using the SODA II process
>
> H_{a4}: The average level of problem-solving confidence of the members between a group using the SODA I process and in a group using the SODA II process will be different

As shown in Table 17 and Table 18, the results of the planned contrast analysis revealed that the main effect on problem-solving confidence between SODA I and SODA II group was not statistically significant, t(60) = 0.612, p = 0.543 (2-tailed). Therefore, the alternative hypothesis was rejected in favor of the null hypothesis. In other words, there is no statistically significant difference in problem-solving confidence between the SODA I and SODA II group. However, as shown in Table 9, the SODA II group (24.43) shows slightly better problem-solving confidence than SODA I group (25.19). This difference could stem from a higher level of ownership in a SODA II group (Franco, 2007; Pidd, 2009). Given that participants created their own merged map in the SODA II group could play a vital role in the difference. Figure 20 presents a boxplot of PSI scores comparison between the SODA I and the SODA II group.

Table 17. Contrast Coefficients for Planned Contrast Analysis

Contrast Coefficients

	Group		
Contrast	Control	SODA I	SODA II
1	0	1	-1

The different signs of the coefficients reflect the direction of the difference (Keppel & Wickens, 2004). Field (2009) explains that the "groups coded with positive weights will be compared against groups coded with negative weight" (p.365). Further, a group that is not involved in comparison will be assigned a weight of 0. As presented in Table 17, the focus is on the pairwise comparison between the SODA I group (positive sign) and the SODA II group (negative sign). In other words, this contrast focuses on the difference between the SODA I and the SODA II group.

Table 18. Contrast Test

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Confidence_Scores	Assume equal variances	1	0.76	1.246	0.612	60	.543

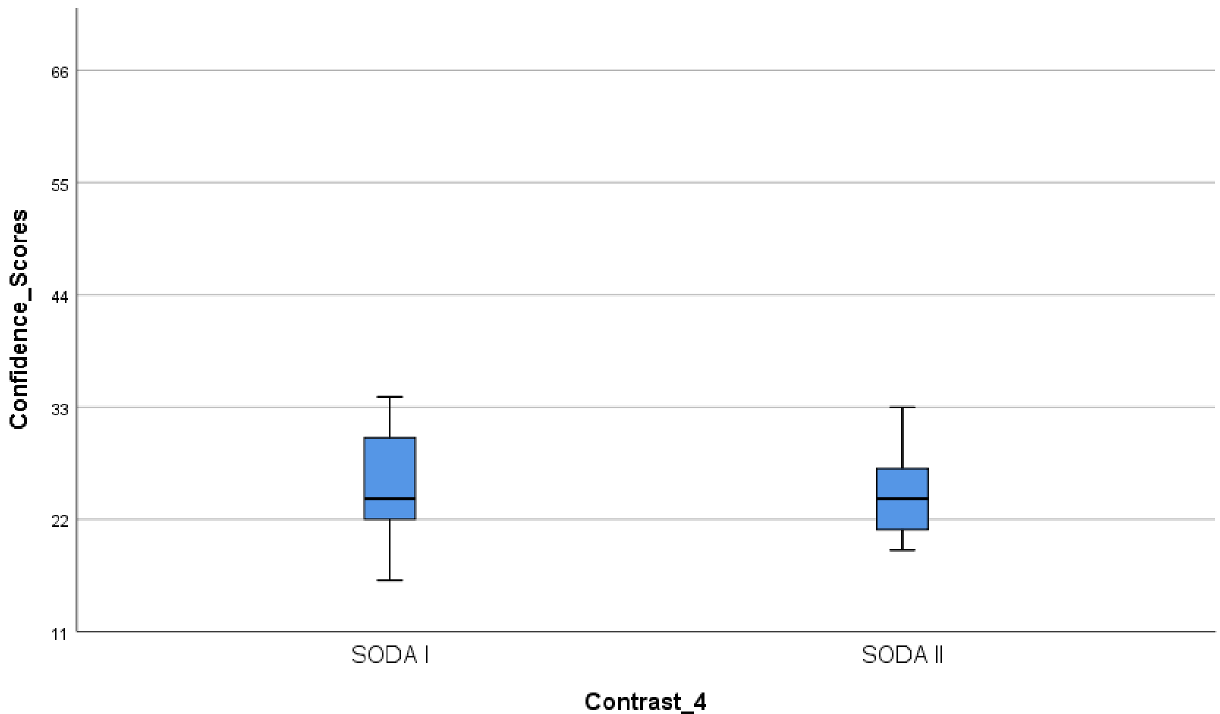

Figure 20. Boxplot of PSI scores by Groups

Analysis of Covariance

Analysis of covariance was conducted to test potential effect of confounding variables. Covariates can be continuous variables that are not part of the main experimental manipulation (i.e., independent variables) but have an influence on the dependent variable (Field, 2009). Analysis of covariance is helpful to identify any variables that influence the dependent variable.

Table 19 indicates the analysis of covariates.

Table 19. Analysis of Covariance

Analysis Of Covariance

Dependent Variable: Confidence_Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	1018.135[a]	7	145.448	8.952	.000	.533	62.666	1.000
Intercept	1155.993	1	1155.993	71.152	.000	.564	71.152	1.000
Work_Exp	.627	1	.627	.039	.845	.001	.039	.054
Education_level	64.655	1	64.655	3.980	.051	.067	3.980	.500
Gender	10.422	1	10.422	.641	.427	.012	.641	.123
Age	14.677	1	14.677	.903	.346	.016	.903	.154
Major	13.751	1	13.751	.846	.362	.015	.846	.148
Group	852.907	2	426.454	26.248	.000	.488	52.497	1.000
Error	893.580	55	16.247					
Total	49638.000	63						
Corrected Total	1911.714	62						

a. R Squared = .533 (Adjusted R Squared = .473)

b. Computed using alpha = .05

The results of the analysis of covariance are the followings:

1. Work experience was not statistically significant related to the problem-solving confidence, $F(1,55) = 0.039$, $p = 0.845$
2. Education level was not statistically significant related to the problem-solving confidence, $F(1,55) = 3.980$, $p = 0.051$
3. Gender was not statistically significant related to the problem-solving confidence, $F(1,55) = 0.641$, $p = 0.427$
4. Age was not statistically significant related to the problem-solving confidence, $F(1,55) = 0.903$, $p = 0.346$
5. Major was not statistically significant related to the problem-solving confidence, $F(1,55) = 0.846$, $p = 0.362$

Though none of these variables is statistically significant on the dependent variable, the education level can be considered marginal. There is an evidence that the instrument used in this experiment has some associations with educational level (Heppner et al., 2004). It was argued that participants with higher educational level tend to score more positively on the problem-solving confidence factor.

Summary of the Hypotheses Tests

The conclusion of the results from the hypothesis tests is presented in Table 20.

Table 20. Summary of Results

	Hypotheses	Result
Hypothesis 1	The average level of problem-solving confidence of the members in a group using SODA process will be different than when SODA process is used	Supported
Hypothesis 2	The average level of problem-solving confidence of the members in a group using SODA I process will be different than when SODA process is used	Supported
Hypothesis 3	The average level of problem-solving confidence of the members in a group using SODA II process will be different than when SODA process is used	Supported
Hypothesis 4	The average level of problem-solving confidence of the members between a group using the SODA I process and in a group using the SODA II process will be different	Not supported

CHAPTER 5

DISCUSSION

Overview

The applications of the Problem Structuring Methods (PSM) are reported in the literature, but not everywhere (Mingers, 2011; Robinson, 2007; Westcombe et al., 2006). Many researchers and practitioners support the use of methods with respect to their value in dealing with messy problems. However, as discussed earlier, the reports of the effectiveness of the methods are often demonstrated through action research. These reports are based on the observations of researchers and could be considered anecdotal. There is a lack of an empirical demonstration of the effectiveness of these methods.

This issue generates a more negative impact to the field, such as a lack of a buy-in from the wider community and stagnation in the development of PSM in academia. This current research explores the difference between the outcome of a group that applies a PSM, Strategic Options Development Analysis (SODA), to make a decision and a group that makes a decision without SODA. The method was selected in this experimental research because it is one of the widely-used PSM and it was used in the previous studies (Cunha & Morais, 2017; Rosenhead & Mingers, 2001; Wu et al., 2016).

The objective of the study was to empirically investigate the effectiveness of Strategic Options Development and Analysis (SODA) by measuring a development of a group consensus through the problem-solving confidence of the participants. This study adapted the Problem-Solving Inventory (PSI) to measure the problem-solving confidence of decision-makers in a messy problem. Given that there is no absolute answer in a messy problem, having reached a group consensus is one of the goals when dealing with a messy problem (Ackermann, 2011; Mingers, 2011). Having a high level of confidence among members is one of the indications that a group consensus is reached (Koriat, 2018; Orive, 1988). Given that confidence is a subjective measure, the similarity of problem-solving confidence of the participants prior to the experiment can be assumed as presented in Figure.

It can also be assumed that there is no Dunning-Kruger Effect in the results of this experiment. The Dunning-Kruger Effect explains "a tendency for people with relatively lower skill levels and knowledge to overestimate their ability to accomplish the task, whereas people with relatively higher skill levels and knowledge would tend to underestimate their ability to complete the task" (Pavel, Robertson, & Harrison, 2012, p. 126). In other words, the Dunning-Kruger Effect describes the relationship between confidence and the actual competency level – overconfidence, more specifically. Given that the participants have similar knowledge of the task and the decision tool used in this research, it is fair to assume that there was no Dunning-Kruger Effect in the results.

Data were consistent with the hypotheses that there are differences between the groups using SODA and the group that did not use SODA. The groups with SODA show a higher level of problem-solving confidence than the group without SODA. The findings confirm that a PSM helps develop a group consensus which is one of the most important goals in dealing with a messy problem. SODA provides a framework for a group to share relevant information, which leads to structured discussions. It seems reasonable to infer that the merged map in SODA groups generates structured discussions that lead to a consensus among members in a group.

A merged map, or a strategic map as called by Pidd (2009), acts as a reference point for the group discussions. Providing a holistic view of a problematic situation, it appeared that the merged map helped members in a group explore future events. It was observed that a what-if scenario analysis was used in the treatment groups which did not occur in control groups. The findings are paralleled with the belief that SODA facilitates "the better management of the process by which the team will arrive at something approaching consensus and both emotional and cognitive commitment to action" (Eden & Ackermann, 2001, p. 21).

On the other hand, the discussions in a control group were unstructured. One of the possible explanations is that there is no reference point of discussion, which leads to a low level of shared understanding and eventually leads to a low level of problem-solving confidence. Given that the members have different pieces of information, each member tends to discuss based solely on their own information. It was observed that each member did not trust other members with respect to the different information. In other words, they did not see the bigger picture of the problematic situation. A lack of shared understanding (a group consensus) might be one of the reasons for showing low problem-solving confidence in the control group.

The time difference is also worth discussing. The average time used in control groups is 26 minutes, while the SODA I and SODA II groups are 35 and 48 minutes, respectively. It was expected that SODA groups would take a longer time to complete the task. The literature discusses a time constraint as one of the challenges in the field (Jenkins, 1998; Leonhardt Kjærgaard & Blegind Jensen, 2014; Mingers & Taylor, 1992). The results of this current study confirm that PSM intervention produces a clear benefit for the use of the time. Participants in the SODA groups show a higher level of problem-solving confidence than participants in the control group.

Based on the results from the fourth hypothesis, the difference in problem-solving confidence between SODA I and SODA II groups was not significant. However, both groups show a high level of problem-solving confidence which shows the development of consensus. This finding is in parallel with the arguments in Pidd (2009) and Ackermann and Eden (2001). Both approaches provide a framework for a group to structure a problem before solving it. According to the results of this current experiment, SODA I and SODA II can be applied interchangeably depending on the problem context and environment.

Implications

This research attempt offer some implications. First, the findings indicate that the use of a PSM in a group decision leads to the development of a group consensus in a messy problem. As elaborated earlier, there is no optimal solution in a messy problem due to the differences in the stakeholders' perception of the problem. Effectively reached a group consensus is one of the goals in a divisive environment. This is because the success starts with the agreement among stakeholders to decide what the problem is. PSM provides a holistic view of the problematic situation based on the available information from multiple stakeholders. It is crucial because a group has a higher chance of committing the Type III error when dealing with a messy problem. The more appropriate courses of action could be surfaced when an ill-structured problem (i.e., different perspectives toward a problem) becomes more structured. The findings of this research implies that a PSM should be incorporated as one of the problem-solving methods in a messy problem.

Second, The results also suggest that using PSM is better than a regular group meeting approach without PSM. As stated earlier, one of the criticisms is a doubt on the contributions of a PSM to the problem-solving process. The attempt to empirically show the difference between a PSM intervention and simply having people to work in a group is very limited. As Robinson (2007) states that "reading about PSMs does not provide a sense of confidence about implementing them (p. 690)." In addition, the invisibility problem of PSM in the United States is also discussed in Mingers (2011). It is argued that, in the U.S., "the view that Soft OR is not real OR is official

(Mingers, 2011, p. 737). The research methodology in this dissertation is well controlled to ensure that a PSM intervention produces a clear benefit in a problem-solving process. Adding more evidence of the effectiveness of a PSM, it is hoped that the dissemination of the usage will increase in a wider communities – especially in the U.S.

Last but not least, given that the sample of this reserch is college students, the results imply that the development of PSM can be achieved in academia. Teaching the concepts of PSM is one of the most important challenges in the community as presented earlier in this document. To acknowledge PSM as a valid OR methods, this challenge needs to be addressed. Ackermann (2011) argues that one of the constraints might stem from the student expectations of a problem-solving process. The author believes that "Students, based on their experience to date, consider that the role of management science/operational research is to produce a single, right answer (Ackermann, 2011, p. 58)." As elaborated throughout this document, the objective of a PSM is not to find the optimal solution as it does not exist in a messy problem. A general concept of PSM is to reach a group consensus through discussions and negotiations among stakeholders. This research provides an evidence to bridge the knowledge gap by showing that a case study can help students develop a better understanding of PSM concepts. The results indicates that the PSM intervention in this research was successful because the difference between the PSM and Non-PSM groups is statistically significant. In addition, it was observed that students expressed their enthusiasm about learning an alternative way to make sense of a problem in a group.

Limitations and Future Research

This study poses some limitations. The sample of college students may not be entirely representative of the larger populations. As discussed earlier, problem-solving confidence varies based on age and experiences (Thornton & Dumke, 2005). This study certainly acknowledges the use of students as a limitation. However, it may be worthwhile considering that the benefit of SODA can be achieved at any level. Future research can address this concern by conducting an experiment in an industry where the decision-makers have a higher level of problem-solving experience. It is also noted in Ackermann and Eden (1997) that there is a need for a real data collection, as opposed to student data

The findings from a small group size might restrict their generalization. However, as discussed earlier, researchers find that the impact of a group decision support tool in a small group (three to four individuals) may be more significant than the impact in the larger-size group (Watson et al., 1988). This study acknowledges this issue and recommends the limited generalization of the findings. Also, the relationships of the participants and the group dynamics are not included in this study. The relationships among the participants in a group may impact the outcome of the experiment. This study addresses this concern by randomly assigned participants to a group. In addition, the members' interactions in a group are not included in this study. The familiarity of the method used (SODA) may also make a significant impact on the outcome of the study. Future research should explore these relationships.

Given the nature of the experimental research, this study is contextually controlled, and the results may not fully apply to reality. It is mainly related to a concern with the familiarity of PSM and the generation of cognitive maps. A SODA workshop usually takes half a day or even more (Westcombe, 2002b). Based on the limitation of time and resources, SODA process used in this study is limited. Future research can address this limitation by exploring different level of familiarity of the method. A pre- and post-experimentaion design would allow for a better understanding of the results when the participants have different level of SODA knowledge. In addition, future research could explore other PSM since the results of this current study is restricted to SODA.

As elaborated earlier, a cognitive map is a representation of how an individual understands the world. As discussed in Eden (1989) and Montibeller and Belton (2006), a cognitive map is a network of related concepts which represents the discourse of a person. However, because of the controlled nature of an experimental study, the predesigned cognitive maps were given to participants. It is due to the limitation of time and the lack of comprehensive training. A SODA workshop usually takes half a day or even more (Westcombe, 2002b). In this research, the given cognitive maps are considered a controlled input for the manipulations. Similar research shows that, giving a graphic organizer (similar to a cognitive map) to the college student participants, rather than having them create their owns, generates a better performance (Stull & Mayer, 2007). The authors argue that the deficiency might be coming from the excessive cognitive demanding during the construction of the graphic organizers. In other words, in the context of this study, giving a cognitive map to the participants reduces the confusion that might occur during the generation of the maps. Even though giving cognitive maps to the participants can be a great control for this study, the construction of their own cognitive maps may affect participants' confidence in the decisions. Future research can address this concern by adding a training, a generation of cognitive mapping, to the experiment.

Next, the findings from a single decision-making task might restrict the generalization of the results. Different decision domains (i.e., scenario) might affect the outcome of the study. The

SODA may be more applicable to some domains. The different levels of complexity of the task can also significantly impact the outcome of the experiment (Stull & Mayer, 2007). Moreover, this study only addressed one variable in a problem-solving process. Other variables still remain for investigation. For example, the level of knowledge generation during a PSM intervention (from both facilitator and participants), the effects of emotions, or emergent leader in a group. Future research should address these variables to further support the effectiveness of a PSM application.

Conclusion

The applications of the Problem Structuring Methods (PSM) in a messy problem have been recognized for decades. These methods are not mathematical, but they are contextual oriented. They aim to explore and structure a problem rather than finding the optimal solution. The application of PSM is appropriate in dealing with a messy problem where there is no absolute solution. Because of their exploratory characteristic, there are doubts regarding the effectiveness of the methods. Researchers have attempted to provide the evidence of the effectiveness of the methods. However, most of the reports are obtained through action research. These reports are considered anecdotal.

This study makes several contributions to address the knowledge gap in the current PSM literature. First, the identification of a consensus as one of the variables concerning an evaluation of a PSM intervention. The variable is selected because consensus is considered one of the goals when dealing with a messy problem. Results from this study also indicate that a PSM intervention generates a group consensus which is a clear benefit in a problem-solving process. These findings underline the efficiency of using PSM as a decision tool in a messy problem. In conclusion, it is hoped that this research can inspire and encourage researchers and practitioners in a wider community to acknowledge the effectiveness of PSM.

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APPENDICES

APPENDIX A: EXEMPT LETTER

OLD DOMINION UNIVERSITY

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

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PROUDLY, AN AAALAC ACCREDITED PROGRAM

Physical Address
4111 Monarch Way, Suite 203
Norfolk, Virginia 23508
Mailing Address
Office of Research
1 Old Dominion University
Norfolk, Virginia 23529
Phone(757) 683-3460
Fax(757) 683-5902

DATE: February 14, 2020

TO: Andres Sousa-Poza, Ph.D.
FROM: Old Dominion University Engineering Human Subjects Review Committee

PROJECT TITLE: [1516719-6] An Investigation on the Effectiveness of Problem Structuring Methods (PSM) in a Group Decision-Making Process
REFERENCE #:
SUBMISSION TYPE: Amendment/Modification

ACTION: DETERMINATION OF EXEMPT
STATUS DECISION DATE:

REVIEW CATEGORY: Exemption category #3

Thank you for your submission of Amendment/Modification materials for this project. The Old Dominion University Engineering Human Subjects Review Committee has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact Stacie Ringleb at 757-683-6363 or sringleb@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Engineering Human Subjects Review Committee's records.

APPENDIX B: NOTIFICATION STATEMENT

NOTIFICATION STATEMENT
OLD DOMINION UNIVERSITY

PROJECT TITLE: An investigation on the Effectiveness of Problem Structuring Methods (PSM) in a Group Decision-Making Process

INTRODUCTION
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research. The purpose of this research is to assess the impact of Strategic Options Development Analysis (SODA) in a messy problem.

RESEARCHERS
Principal Investigators: Andres Sousa-Poza, Ph.D.
Batten College of Engineering & Technology
Department of Engineering Management and Systems Engineering

Investigator: Ying Thaviphoke
Batten College of Engineering & Technology
Department of Engineering Management and Systems Engineering

DESCRIPTION OF RESEARCH STUDY
If you decide to participate, you will join a study involving research of a group decision-making task. You will be solving a hypothetical problem-solving task in a group scenario. After the completion of the task, you will be asked to complete a survey. If you decide to participate, your participation will last for 30 to 60 minutes in a closed room in the Department of Engineering Management and Systems Engineering. This research study will be a single session in one day. Approximately 70 students will be participating in this study.

EXCLUSIONARY CRITERIA
You should have completed the questions regarding the Strategic Options Development Analysis, the winter survival exercise, and your work experience. To the best of your knowledge, you should not have the exposure of both Strategic Options Development Analysis and the winter survival exercise and should not have an extensive decision-making experience (5+ years).

RISKS AND BENEFITS
RISKS: If you decide to participate in this study, there should be no risk involved. However, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: The main benefit for participating in this study is to learn about a new decision-making tool that participants can use in future decision-making situations.

COSTS AND PAYMENTS
Your participation in this study is voluntary. Yet the researchers recognize that your participation may pose some demand on your time. As an incentive, the researchers will include your name in a pool to receive an iPad. Moreover, you will earn extra credits if you are enrolled in ENMA 301, 302, 421, 480 in Spring 2020. The extra credit assignment will take approximately 30-60 minutes (the same amount of time as participating in the research study).

NEW INFORMATION
If the researchers find new information during this study that would reasonably change your decision about participating, it will be provided at your preferred email addresses.

CONFIDENTIALITY
The researchers will take reasonable steps to keep private information, such as your names, age, education level, and work experience confidential. The researcher will remove identifiers from all identifiable private information collected. Following data entry, the raw data will be kept in a locked drawer which is located in the Department of Engineering Management and Systems Engineering, Old Dominion University. The raw data will also be destroyed after the final submission of the dissertation. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify the participants. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO to the participation. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might otherwise be entitled. Moreover, if you decided not to participate in this study, you can still earn extra credits through the alternative extra credit assignment if you are enrolled in ENMA 301, 302, 421, 480 in Spring 2020. The extra credit assignment will take approximately 30-60 minutes (the same amount of time as participating in the research study).

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent does not waive any of your legal rights. However, in the event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact the principal investigator Dr. Andres Sousa-Poza at 757-683-4734, Dr. Tancy Vandecar-Burdin the current IRB chair at 757-683-3802 at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By staying in this room, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and potential risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Principal Investigators: Andres Sousa-Poza, Ph.D.
Tel: 757-683-4734

Investigator: Ying Thaviphoke
Tel: 703-889-0142

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. Tancy Vandecar-Burdin, the current IRB chair, at 757-683-3802, or the Old Dominion University Office of Research, at 757-683-3460.

And most importantly, if you stay in this room, you are telling the researcher YES, that you agree to participate in this study. The researcher will give you a copy of this form for your records.

INVESTIGATOR'S STATEMENT

I certify that I have explained to this participant the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws and promise compliance. I have answered the participant's questions and have encouraged him/her to ask additional questions at any time during the course of this study.

Investigator's Printed Name & Signature	**Date**

APPENDIX C: SCENARIOS AND QUESTIONNAIRES

Please answer the following questions before proceeding to the next section.

1. Please circle the gender identity you most identify

   (Female, Male, Other, Prefer not to answer)

2. Please provide your age: ___________

3. What is your major? ____

4. Please circle the education level you are pursuing: (Undergraduate, Master)

<u>A document for member I in a **control group**</u>

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Mid-January is the coldest time of the year in Minnesota and Manitoba. The first problem the survivors' face, therefore, is to preserve their body heat and protect themselves against its loss. This problem can be met by building a fire, minimizing movement and exertion, and using as much insulation as possible. The participants have just crash-landed. At the temperatures given, the loss of body heat through exertion is a very serious matter. Once the survivors have found ways in which to keep warm, their most immediate problem is to provide signaling methods to attract the attention of search planes and search parties. Thus, all the items the group has must be assessed according to their value in signaling the group's whereabouts.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together.

Based on given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

A document for member II in a **control group**

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Many individuals tend to overlook the enormous shock reaction this has upon the human body, and the death of the pilot and co-pilot increases the shock. Decision making under such conditions is extremely difficult. Such a situation requires a strong emphasis upon the use of reasoning not only to make decisions, but also to reduce the fear and panic every person would naturally feel. Along with fear, shock reaction is manifested in the feelings of helplessness, loneliness, and hopelessness. These feelings have brought about more fatalities than perhaps any other cause in survival situations. Through the use of reasoning, hope can be generated. Certainly, the state of shock means that movement of individuals should be at a minimum and that an attempt to calm them should be made. The eighty miles to the nearest known town is a very long walk even under ideal conditions, particularly if one is not used to walking such distances. Under the circumstances of being in shock, dressed in city clothes, having deep snow in the woods, and a variety of water barriers to cross, to attempt to walk out would mean almost certain death from freezing and exhaustion.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together.

Based on given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

<u>A document for member III in a **control group**</u>

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Before taking off a pilot always has to file a flight plan. The flight plan contains the vital information regarding the flight, such as the course, speed, estimated time of arrival, type of aircraft, number of people on board, and so on. Search-and-rescue operations would begin shortly after the plane failed to arrive at its destination at its estimated time of arrival. Walking to the nearest town may enhance the opportunity to meet the rescue team.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together.

Based on given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

Working as a group in a decision task has been argued to be superior than working as an individual.

Decision Task

According to the information the team has, please rank the following items according to their importance to your survival (“1” for the most important and “15” for the least important).

_____ Compress kit (with 28-ft., 2-in. gauze)

_____ Sectional air map made of plastic

_____ Ball of steel wool

_____ 30 feet of rope

_____ Cigarette lighter (without fluid)

_____ Family-size chocolate bar (one per person)

_____ Loaded .45 caliber pistol

_____ Flashlight with batteries

_____ Newspaper (one per person)

_____ Quart of 85-proof whiskey

_____ Compass

_____ Extra shirt and pants for each survivor

_____ Two ski poles

_____ Knife

_____ Can of shortening

<u>A document for **treatment groups**</u>

Please answer the following questions before proceeding to the next section.

1. Please circle the gender identity you most identify

   (Female, Male, Other, Prefer not to answer)

2. Please provide your age: ___________

3. What is your major? ____

4. Please circle the education level you are pursuing: (Undergraduate, Master)

Given the scenario below, please complete the following task:

<u>A document for member I in the **treatment groups**</u>

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Mid-January is the coldest time of the year in Minnesota and Manitoba. The first problem the survivors' face, therefore, is to preserve their body heat and protect themselves against its loss. This problem can be met by building a fire, minimizing movement and exertion, and using as much insulation as possible. The participants have just crash-landed. At the temperatures given, the loss of body heat through exertion is a very serious matter. Once the survivors have found ways in which to keep warm, their most immediate problem is to provide signaling methods to attract the attention of search planes and search parties. Thus, all the items the group has must be assessed according to their value in signaling the group's whereabouts.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

Please use the cognitive map below to make a decision.

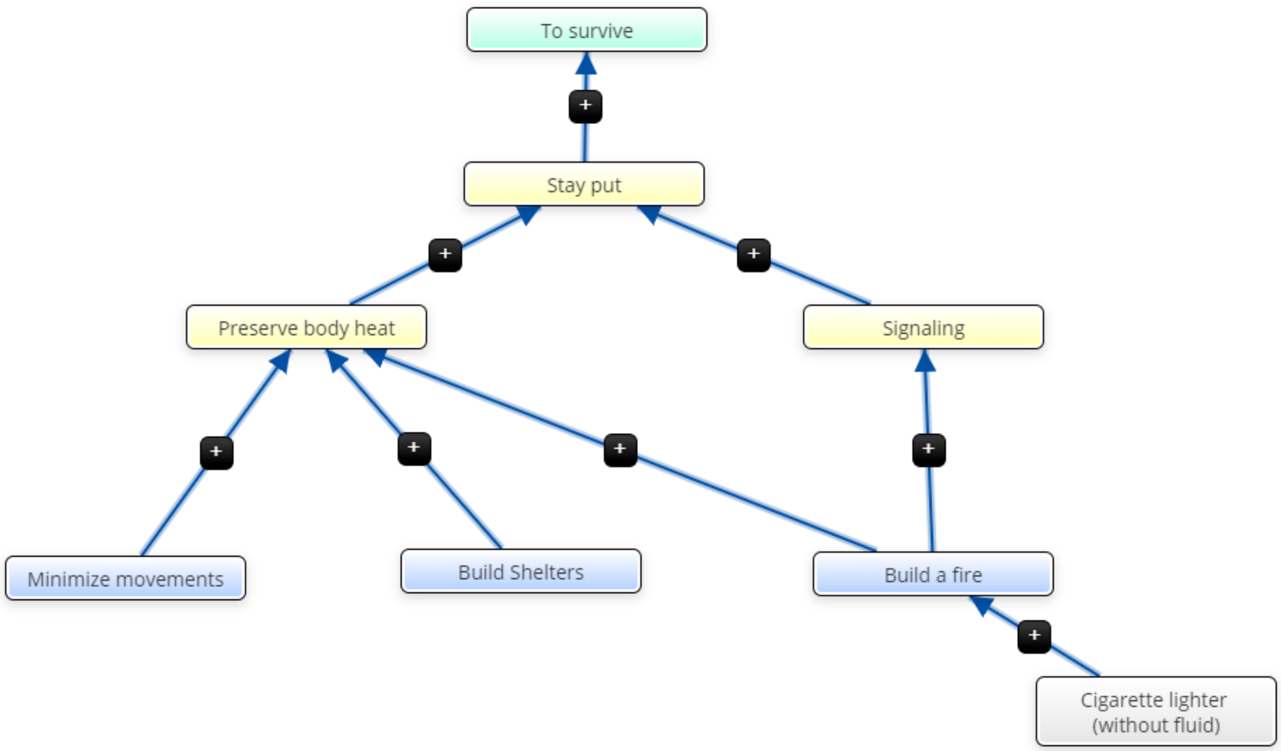


Figure information:
A cognitive map is a graphical representation of the problematic situation we are facing. As you can see from this map, the goal in this situation is "To survive" which is a **green concept** in the picture (the highest in the hierarchy). The **yellow concepts** are the strategies to achieve the goal, with only one DIRECT impact ("Stay put"). The other two have indirect impacts to the goal. The **blue concepts** are the actions to achieve the strategies. The **grey concept** is a resource that impacts the actions. The arrows indicate the mean-ends relationships (plus means positive and minus mean negative) among nodes.
An example of a map interpretation: "Build a fire" will positively lead to both "Preserve body heat" and "Signaling". "Preserve body heat", "Signaling", and "Stay put" will positively lead "To survive", our goal.

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

<u>A document for a member II in the **treatment groups**</u>

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Many individuals tend to overlook the enormous shock reaction this has upon the human body, and the death of the pilot and co-pilot increases the shock. Decision making under such conditions is extremely difficult. Such a situation requires a strong emphasis upon the use of reasoning not only to make decisions, but also to reduce the fear and panic every person would naturally feel. Along with fear, shock reaction is manifested in the feelings of helplessness, loneliness, and hopelessness. These feelings have brought about more fatalities than perhaps any other cause in survival situations. Through the use of reasoning, hope can be generated. Certainly, the state of shock means that movement of individuals should be at a minimum and that an attempt to calm them should be made. The eighty miles to the nearest known town is a very long walk even under ideal conditions, particularly if one is not used to walking such distances. Under the circumstances of being in shock, dressed in city clothes, having deep snow in the woods, and a variety of water barriers to cross, to attempt to walk out would mean almost certain death from freezing and exhaustion.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

Please use the cognitive map below to make a decision.

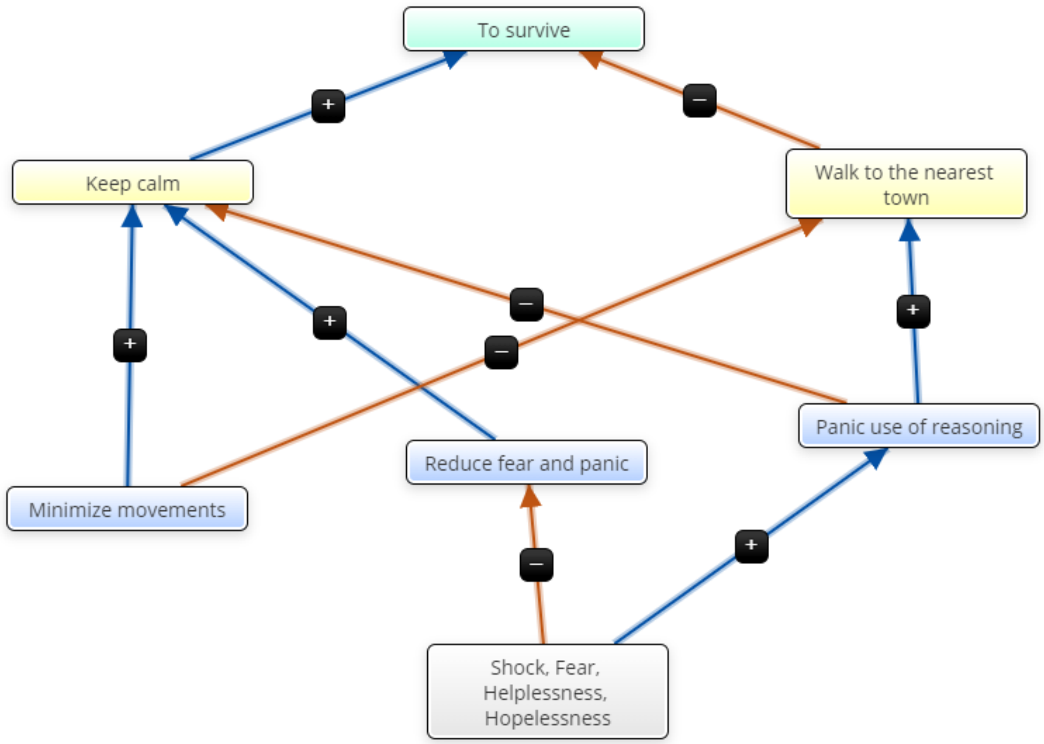


Figure information:
A cognitive map is a graphical representation of the problematic situation we are facing. As you can see from this map, the goal in this situation is "To survive" which is a **green concept** in the picture (the highest in the hierarchy). The **yellow concepts** are the strategies to achieve the goal, with two DIRECT impacts ("Keep calm" and "Walk to the nearest town"). The **blue concepts** are the actions to achieve the strategies. The **grey concept** is a resource that impacts the actions. The arrows indicate the mean-ends relationships (plus means positive and minus mean negative) among nodes.
An example of a map interpretation: "Shock, Fear, Helplessness, Hopelessness" positively lead to a "Panic use of reasoning" which would trigger the "Walk to the nearest town". As it is provided in the information, "Walk to the nearest town" would negatively impact the "To survive" – almost certain death from freezing and exhaustion.

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

<u>A document for a member III in the **treatment groups**</u>

The Background Situation

You have just crash-landed in the woods of North Minnesota and Southern Manitoba. It is 11:32 a.m. in mid-January and the range of the temperature is -25F to -40F. The small plane in which you were traveling has been completely destroyed except for the frame. The pilot and co-pilot have been killed, but no one else is seriously injured. The crash came suddenly before the pilot had time to radio for help or inform anyone of your position. Since your pilot was trying to avoid a storm, you know the plane was considerably off course. The pilot announced shortly before the crash that you were eighty miles northwest of a small town that is the nearest known habitation. You are in a wilderness area made up of thick woods broken by many lakes and rivers. The last weather report indicated that the temperature would reach minus twenty-five degrees Fahrenheit in the daytime and minus forty at night. You are dressed in winter clothing appropriate for city wear – suits, pantsuits, street shoes, and overcoats.

Before taking off a pilot always has to file a flight plan. The flight plan contains the vital information regarding the flight, such as the course, speed, estimated time of arrival, type of aircraft, number of people on board, and so on. Search-and-rescue operations would begin shortly after the plane failed to arrive at its destination at its estimated time of arrival. The rescue team may be able to find the nearest town first since it is the nearest known habitation. Walking to the nearest town may enhance the opportunity to meet the rescue team.

While escaping from the plane your group salvaged the fifteen items as follows: Compass, Compress kit (with 28-ft., 2-in. gauze), Ball of steel wool, Quart of 85-proof whiskey, Extra shirt and pants for each survivor, Family-size chocolate bar (one per person), Cigarette lighter (without fluid), Newspaper (one per person), Can of shortening, Flashlight, Ski poles, Piece of rope, A 0.45-caliber pistol, A knife, Sectional air map made of plastic. You may assume that the group has agreed to stick together

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

Please use the cognitive map below to make a decision.

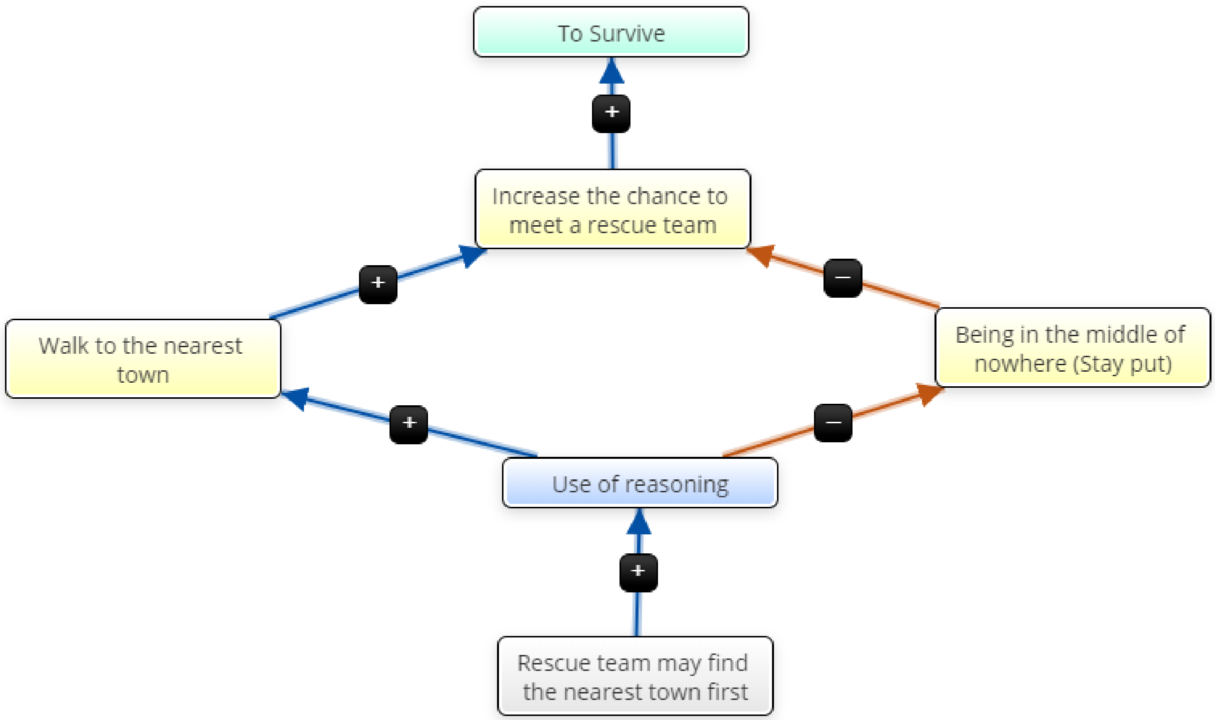
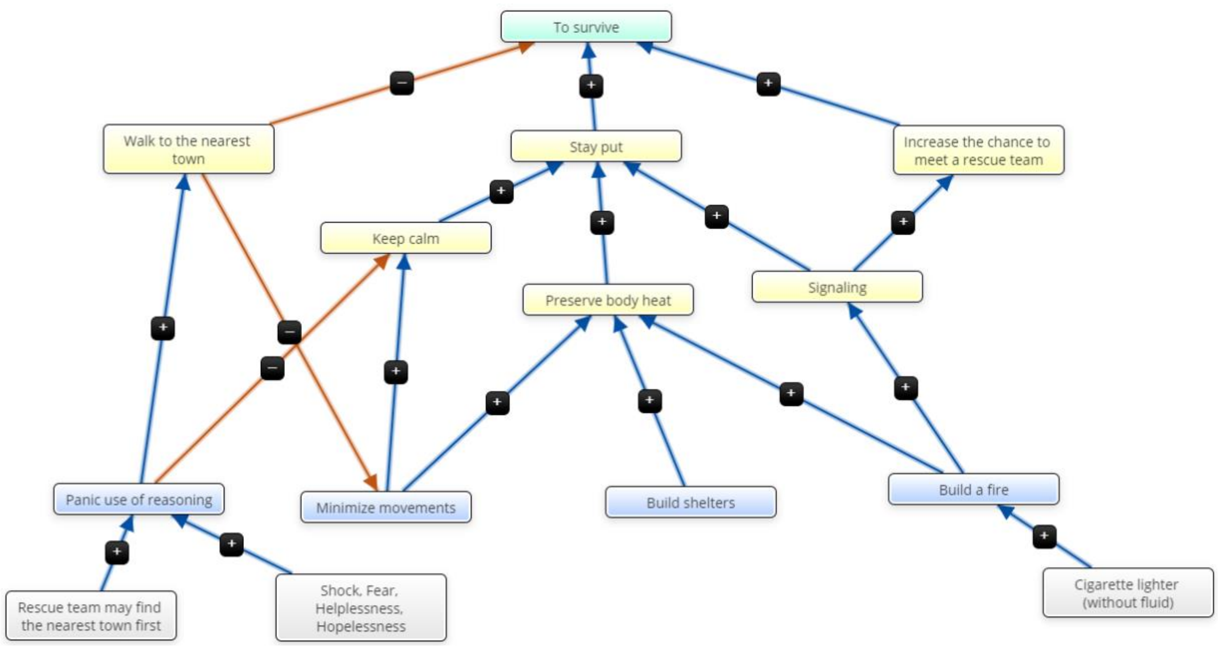


Figure information:
A cognitive map is a graphical representation of the problematic situation we are facing. As you can see from this map, the goal in this situation is "To survive" which is a **green concept** in the picture (the highest in the hierarchy). The **yellow concept** are the strategies to achieve the goal, with one DIRECT impact ("Increase the chance to meet a rescue team"). The **blue concept** is the means to achieve the strategies. The **grey concept** is a <u>resource</u> that impacts the actions. The arrows indicate the mean-ends relationships (plus means positive and minus mean negative) among nodes.
An example of a map interpretation: The thought that "Rescue team may find the nearest town first" triggers the "Use of reasoning" which positively leads to "Walk to the nearest town". "Walk to the nearest town" may "increase the chance to meet a rescue team" which is believed to positively lead "To survive".

Based on the given information, please circle the following strategies in which you think it would be the most appropriate to survive in this situation.

Stay put **Walk to the nearest town**

The predesigned merged map



Predesigned Scripts for a Merged Map:

- As you may aware from your individual map, the purpose of a cognitive map is to structure our thoughts through the **chains of argumentation** by writing down concepts and their relationships among them.
- This map should be created from all of your information that you can collect. The map should do the followings:
    1. Capture **all relevant concepts** along with their relationships (both + and -)
    2. The arrows show the relationships between concepts
    3. Present the means to identify **Goals**, S**trategies, Actions, and Resources**
    4. Identify inconsistencies in the arguments (for example, is it really true that **walk to the nearest town → Increase the chance to meet a rescue team**?)
- Map construction guideline. This merged map was built by the followings:
    1. The ideas (concepts) should be in succinct form (verb + objective)
    2. Build up the hierarchy (structure the map using the means-ends analysis)
        - Layers of importance – Goal → Strategies → Actions → Resources
        - Layers of importance – Goal ← Strategies ← Actions ← Resources
        - After having goals, strategies, actions, and resources, mark (colored) them
- As a team, you can add or remove any concepts or arrows as you see appropriate.

Decision Task

Your task is to rank these items according to their importance to your survival. According to the information that your team has, please rank the following items according to their importance to your survival ("1" for the most important and "15" for the least important).

_____ Compress kit (with 28-ft., 2-in. gauze)

_____ Sectional air map made of plastic

_____ Ball of steel wool

_____ 30 feet of rope

_____ Cigarette lighter (without fluid)

_____ Family-size chocolate bar (one per person)

_____ Loaded .45 caliber pistol

_____ Flashlight with batteries

_____ Newspaper (one per person)

_____ Quart of 85-proof whiskey

_____ Compass

_____ Extra shirt and pants for each survivor

_____ Two ski poles

_____ Knife

_____ Can of shortening

APPENDIX D: PROBLEM-SOLVING CONFIDENCE QUESTIONNAIRES

	Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	*Strongly Disagree*
Solving this problem in a group using the given approach, I am almost certain that we can solve the problem	1	2	3	4	5	6
Given enough time and effort, I believe I can solve this problem with a group using the given approach.	1	2	3	4	5	6
When I become aware of a problem, working in a group using the given approach helps me to find out exactly what the problem is.	1	2	3	4	5	6
Working in a group using the given approach helps me solve the problem even though initially no solution is immediately apparent.	1	2	3	4	5	6
Many problems I face are too complex for me to solve.	1	2	3	4	5	6
Working in a group using the given approach, I make decisions and am happy with them.	1	2	3	4	5	6
When faced with a novel situation I have confidence that I can handle problems that may arise working in a group using the given approach.	1	2	3	4	5	6
I trust my ability to solve new and difficult problems working in a group using the given approach	1	2	3	4	5	6
After making a decision, the outcome I expected usually matches the actual outcome.	1	2	3	4	5	6
When confronted with a problem, I am unsure of whether I can handle the situation.	1	2	3	4	5	6
I am usually able to think up creative and effective alternatives to solve a problem.	1	2	3	4	5	6

APPENDIX E: PREDESIGNED SCRIPTS

Control Group: ___________________

1. Greetings
    a. Consent form
    b. Ask if they came from any classes
2. Provide documents
    a. Background case
    b. Individual information
3. **FACILITATION:** "Working as a team has been proven to be better than solving problems individually." "Given that each member possesses a different piece of information, working as a group in a decision task has been argued to be superior than working as an individual"
    a. Ask participants to work as a group
    b. Ask participants to complete the task as a group
        i. TIME: __________________________
4. Ask each participant to complete the survey individually
    a. "According to the team discussion and the approach, please fill out this survey"

Treatment 1 Group: ___________________

1. Greetings
    a. Consent form
    b. Ask if they came from any classes
2. Provide documents
    a. Background case
    b. Individual information
3. **FACILITATION:** SODA I process
    a. Provide individual maps – **"Same information, different representation of the problem"**
        i. Provide some time for the participants to "make sense" of the map. Do they agree with the map? If they don't, they can modify the given map
        ii. Make sure that they are aware of Goal, Strategy, Action, and Resource
    b. Provide the merged map
        i. **Predesigned scripts.** Do they agree with the map? If they don't, they can modify the given map
    c. Ask participant to complete the task as a group
        i. TIME: __________________________
4. Ask each participant to complete the survey individually
    a. "According to the team discussion and the approach, please fill out this survey"

Treatment 2 Group: ___________________

2. Greetings
   a. Consent form
   b. Ask if they came from any classes
3. Provide documents
   a. Background case
   b. Individual information
4. **FACILITATION:** SODA I process
   a. Provide individual maps – **"Same information, different representation of the problem"**
      i. Provide some time for the participants to "make sense" of the map. Do they agree with the map? If they don't, they can modify the given map.
      ii. Make sure that they are aware of Goal, Strategy, Action, and Resource
   b. Ask participants to create a merged map as a group
      i. **Predesigned scripts**
   c. Ask participant to complete the task as a group
      i. TIME: __________________________
5. Ask each participant to complete the survey individually
   a. **"According to the team discussion and the approach, please fill out this survey.**

Predesigned Scripts for a Merged Map:

- As you may aware from your individual map, the purpose of a cognitive map is to structure our thoughts through the **chains of argumentation** by writing down concepts and their relationships among them.
- This map should be created from all of your information that you can collect. The map should do the followings:
  1. Capture **all relevant concepts** along with their relationships (both + and -)
  2. The arrows show the relationships between concepts
  3. Present the means to identify **Goals**, S**trategies, Actions, and Resources**
  4. Identify inconsistencies in the arguments (for example, is it really true that **walk to the nearest town → Increase the chance to meet a rescue team**?)
- Map construction guideline. This merged map was built by the followings:
  1. The ideas (concepts) should be in succinct form (verb + objective)
  2. Build up the hierarchy (structure the map using the means-ends analysis)
     - Layers of importance – Goal → Strategies → Actions → Resources
     - Layers of importance – Goal ← Strategies ← Actions ← Resources
     - After having goals, strategies, actions, and resources, mark (colored) them
- As a team, you can add or remove any concepts or arrows as you see appropriate.

APPENDIX F: RELIABILITY ESTIMATES – PROBLEM-SOLVING CONFIDENCE

Case Processing Summary

		N	%
Cases	Valid	63	100.0
	Excluded[a]	0	.0
	Total	63	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.811	.826	11

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	2.505	1.698	4.619	2.921	2.720	.994	11
Item Variances	.737	.504	1.117	.613	2.215	.036	11

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
27.56	30.864	5.556	11

APPENDIX G: NORMALITY

Descriptives

	Group		Statistic	Std. Error
Confidence	Control	Skewness	-.675	.501
		Kurtosis	-.862	.972
	SODA I	Skewness	.115	.501
		Kurtosis	-.639	.972
	SODA II	Skewness	.569	.501
		Kurtosis	-.228	.972

VITA

EDUCATION

Ph.D., Engineering Management and Systems Engineering
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RESEARCH INTERESTS

Decision making: Group decision, Strategic Options Development and Analsis, Problem structuring methods, Stakeholder analysis, Project Management, Method choice, Decision-support modeling, Risk management
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EXPERIENCE

Instructor | 2016 – Present
Graduate Research & Teaching Assistant | 2015 – Present
Department of Engineering Management and Systems Engineering,
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Assistant Project Manager | 2012 – 2013
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