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First Principles Thinking for Societal Problem-Solving

A Manual to Generate Innovative Solutions to Today's Challenges

Factory for Innovative Policy Solutions

Factory for Innovative Policy Solutions

17 October 2019

FIRST EDITION

www.innovativepolicysolutions.org

EXECUTIVE SUMMARY

The world of today is more interconnected and dynamic than ever before. Although this fact has come with many benefits, it has also resulted in an ever-growing number of societal challenges around the globe. The lack of existing solutions to these challenges calls for new methods of developing innovative and practical ideas.

First principles thinking is a technique that guides you to systematically come up with new solutions by way of reverse-engineering societal challenges. It encourages you to critically question the assumptions of the challenge and break it down into basic components, after which you ask more critical questions that will surely inspire new ideas in a way that reassembles the components from the ground up. The methodology itself dates back to classical antiquity, when it was first introduced by Aristotle and later applied by Euclid in his geometrical proofs. It was then further developed during the Renaissance by Descartes' foundationalism as well as in the age of Enlightenment through Kant's writings on reason. At the onset of modernity, Marx experimented with pairing first principles with ideology.

However, contemporary works on the method have not gone much further than simply listing the action steps, which leaves much open to the intuition and interpretation of the applicant. Some aspiring first principles thinkers appreciate this more than others. For those who would like some more guidance, we have outlined additional procedures and insights. We furthermore elaborate on two additional steps that we find are particularly relevant in the context of societal problem-solving. In doing so, we also apply each step to the challenge of ensuring sufficient access to fresh water for residents of Cape Town, after which we invite you to do the same for your challenge.

Here you find each step explained in brief:

I. ***Identify your objective***. Transform your societal challenge into an objective statement that captures what needs to be improved, for whom and in which locality, possibly with a deadline, without demarcating it further than this. The statement should indicate whether you seek to tackle a challenge entirely or partially.

II. ***List your obstacles***. Identify all obstacles in the way of your objective. Depending on whether you seek to tackle a challenge entirely or partially, you can decide to embark on either those obstacles that are individually necessary and jointly sufficient to achieve your objective, or those that are (un)related to your background.

III. ***Question your assumptions***. Question the assumptions that underlie each obstacle in a disciplined, rigorous and thoughtful manner, alone or with a partner, through Socratic questioning. Look for evidence, consider alternative perspectives, decompose the elements of assumptions and examine the implications.

IV. ***Uncover your first principles***. Answer your Socratic questions to discover the fundamental truths: your first principles. You can answer the questions intuitively through an educated guess or with the aid of your search engine, as long as the answers are founded in science and deduced as much as is reasonably possible.

V. ***Come up with new ideas***. Pose 'how can we …' questions linking the first principles to your obstacles with the goal to come up with new ideas, and ask follow-up questions to make your ideas more actionable. Make sure that you write down all the ideas that come to mind and try to merge them with different questions and ideas.

VI. ***Refine your ideas***. Reduce your ideas to a manageable volume through a simple pass/fail exercise, and settle on a number of evaluation criteria for your ideas. Assess and refine the remaining ideas according to your criteria by way of Socratic questioning, identifying first principles and asking 'how can we …' questions.

VII. ***Select your solutions***. Select which ideas will be taken to the implementation table. Depending on how you selected your obstacles in step II, your selection can take place according to which ideas are individually necessary and/or jointly sufficient to overcome your obstacles, or by way of an evaluation matrix.

Though this manual addresses the steps of first principles thinking in depth, we go on to demonstrate how it compares to other societal problem-solving methods. In stark contrast to first principles thinking, analogical thinking seeks to duplicate solutions that have worked in similar contexts to a given challenge rather than develop unique and original ideas. More in line with first principles thinking, however, analytical thinking focuses on the root causes of a particular challenge to develop solutions for it. Design thinking is the most people-centred approach, as it concentrates primarily on the stakeholders in any particular challenge, while lateral thinking looks beyond the challenge in question to draw inspiration from other areas to produce creative solutions. Finally, computational thinking aims to deconstruct challenges into individual variables in order to create solutions based on the results of carefully formulated algorithms. Finally, we look at the scientific method to demonstrate the role that first principles play in hypothesis creation through the process of abductive, deductive and inductive reasoning.

FOREWORD

From its founding, the Factory for Innovative Policy Solutions (FIPS) has seen itself as an international and inter-disciplinary working group, inclusive to all thinkers who are passionate about confronting societal challenges, no matter their academic or professional backgrounds. In fact, we believe that such a diversity in knowledge, skills and experience is necessary for addressing the complex challenges of an increasingly globalised and rapidly changing world. For innovative thinkers, no problem is off the agenda and no solution is off the table. Founded on these beliefs, and realising that traditional problem-solving methods alone are not always effective in confronting all of today's societal challenges, FIPS first needed to be equipped with a set of appropriately innovative problem-solving tools to produce the solutions we wish to deliver to those in a position to implement them and bring about societal change. The tools adopted for this task came in the form of first principles thinking, an approach to problem-solving that, although rooted in centuries of philosophical thought, remains under-developed and under-valued in the various fields that constitute contemporary public policy.

First principles thinking, unlike other problem-solving methods that emphasise thinking by analogy or continuing the work of others, requires the problem-solver to question everything he or she knows about the problem at hand and start searching for solutions from scratch—from the very first principles. In order to apply first principles thinking to its own work with societal challenges, FIPS drew inspiration from a wide range of other methodologies and techniques to create a process for developing innovative solutions that was both practical and systematic. What follows is an actionable, step-by-step manual accessible to anyone who is passionate and serious about finding solutions to societal challenges, no matter how great or intimidating they may appear initially. The steps outlined in this manual are intended to illustrate an application of first principles thinking that has served us in our work, but they need not be regarded as a "recipe" to be accepted by all problem-solvers equally or applied to every societal challenge uniformly. As every person thinks and works differently, we encourage you to experiment with various applications of the information found in this manual and use it to find an approach to problem-solving that is most suitable for you.

That being said, neither creative genius nor prior experience with societal problem-solving are required in order to benefit from the contents of this manual, and there is no set profile for the successful first principles thinker. Indeed, first principles thinking can be mastered and applied by anyone: students and professors, scientists and scholars, policymakers and philosophers as well as entrepreneurs or professionals from all fields and walks of life. All that is necessary is a passion for a problem to be tackled, an open and inquisitive mindset, and the dedication

to commit until innovative solutions are produced. If you believe that these qualities describe you, then we invite you to begin your journey to become a first principles thinker.

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PART 1 - INTRODUCTION

1.1. The history and development of first principles thinking[i]

The first account of *the methodical use of first principles* as a problem-solving technique dates back to ancient Greece, when it was proposed by Aristotle in his works 'Metaphysics' and 'Physics'. In the former, Aristotle defines first principles as "the first basis from which a thing is known," while in the 'Physics' he explains that "in the science of nature as elsewhere, we should try first to determine questions about the first principles" because the "proper direction of our road is from things better known and clear to us, to things that are clearer and better known by nature; for the things known to us are not the same as the things known unconditionally".[1]

In other words, by warning the problem-solver never to accept common knowledge unquestioningly, Aristotle makes an early reference to epistemology, the branch of philosophy concerned with understanding the nature of knowledge itself. How do we go about knowing things? How do we know what is true and what is false? How can we determine what is a practical solution and what is not? All these basic epistemological questions can only be answered by deconstructing what we already know—or what we think we know—into first principles.

While Aristotle's work dealt largely with the theoretical notion of first principles, the method was notably applied in practice by his contemporary Euclid, whose ground-breaking mathematical treatise 'Elements' used an indispensable set of first principles to establish what today are considered fundamental geometrical proofs. Book I of the 'Elements' begins by providing a number of relevant definitions to conceptualise the terminology—point, line, circle, etc.—that would be used to present five first principles, called postulates or axioms, which serve as the basis for all of his later proofs: (1) a straight line segment may be drawn from any given point to any other; (2) a straight line may be extended to any finite length; (3) a circle may be described with any given point as its centre and any distance as its radius; (4) all right angles are congruent; and (5) if a straight line falling on two straight lines makes the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than two right angles.[2] Understanding that these

[i] An earlier version of this section first appeared as the article: Grass, K. (2019). "Who Uses First Principles Thinking and Why You Should Become one of Them". *Factory for Innovative Policy Solutions*. Retrieved from https://www.innovativepolicysolutions.org/articles/who-uses-first-principles-thinking-and-why-you-should-become-one-of-them

five principles are unconditionally true—and apparently not bothered by the fact that the last might be a bit difficult to read—Euclid was able to use them to prove hundreds of geometric propositions, perhaps most famously the Pythagorean Theorem, which states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides ($a^2 + b^2 = c^2$).

Though much of ancient philosophy was abandoned in the Medieval Ages, first principles thinking experienced a revival during the Renaissance, when René Descartes began to introduce foundationalism into the Western epistemological tradition. The foundationalism of Descartes, itself largely based on Aristotelian thought and Socratic questioning, argued for the justification of any commonly held beliefs with fundamental beliefs, or first principles. This methodological approach, known as Cartesian doubt, had a profound impact on the development of the modern scientific method, which stresses the use of empirical trials and various forms of reasoning to either accept or reject hypotheses. Of these various forms of reasoning, inductive and deductive reasoning in particular exemplify the application of first principles thinking to reach conclusions. While the inductive approach relies on first principles in the form of specific observations to build general theories, deductive reasoning utilises them to create a top-down system of logic in which specific conclusions are drawn from basic premises, as in the example: (1) All men are mortal; (2) Descartes is a man; therefore (3) Descartes is mortal.

As the Renaissance gave way to the Enlightenment, new generations of philosophers continued to explore the use of first principles. In his ‘Critique of Pure Reason’, Immanuel Kant contributed to the epistemological debate by analysing the relationship between “a priori” knowledge, which is derived from nature, and “a posteriori” knowledge, which is acquired through experience.[3] Kant’s work laid the groundwork for what would become the philosophical school of idealism, or the belief that all human knowledge is subjective and mentally constructed through experience. The idealist tradition was, in turn, inherited by the Romantic thinker Georg Wilhelm Friedrich Hegel, whose philosophical approaches had a profound impact on Karl Marx after the Industrial Revolution. Marx advocated the ideological employment of first principles as a tool for making political criticism and promoting class consciousness. In a letter to his colleague Arnold Ruge, titled ‘A Ruthless Criticism of Everything Existing’, Marx argues that when making an effective political criticism, “we do not confront the world in a doctrinaire way with a new principle: Here is the truth, kneel down before it! We develop new principles for the world out of the world’s own principles. We do not say to the world: Cease your struggles, they are foolish; we will give you the true slogan of struggle. We merely show the world what it is really fighting for, and consciousness is something that it has to acquire, even if it does not want to”.[4]

Although their value to the historical development of philosophical theory may be clear, how are first principles being used in practice in the 21st century? Today, first principles thinking is experiencing a comeback in the business world, as it has already been endorsed by several pioneering and successful entrepreneurs. Among the most notable proponents of first principles thinking from the private sector is Elon Musk, founder and chief executive officer of a number of highly innovative companies like Tesla and SpaceX. While Musk's promotion of first principles thinking serves to show the great versatility of the problem-solving method, our focus hereafter will be to harness the power of first principles and apply them to the sphere of public policy. Thus, keeping what we already know about first principles thinking in mind, let us begin our search for innovative ideas for policy solutions to societal challenges.

1.2. What are societal challenges?

A *societal challenge*, broadly speaking, is any issue that affects the collective welfare of a community. These issues can vary greatly in their scope and urgency, from improving general public sanitation to distributing vaccines in the wake of an epidemic. Likewise, the communities affected by these issues vary greatly too, as societal challenges can be identified in remote villages, metropolitan cities, rural regions or industrialised countries. In other words, wherever there are people, there are and always will be societal challenges. Moreover, as the societies of our world become increasingly globalised and interconnected, so do the challenges that they face. For this reason, both floods in Venice and droughts around the Dead Sea—two challenges that, strictly speaking, are geographically limited and affect relatively small communities of people—are, in fact, linked to the much broader and more serious challenges of global warming and climate change. Similarly, while the European refugee crisis may be considered a policy dilemma of the European Union and its Member States, the challenge is directly linked to the prolonged conflicts in Syria and the greater Middle East.

Now, having identified what a societal challenge is, what remains to be answered is whose responsibility it is to confront such challenges. Traditionally, it has been the responsibility of governments, either local or national, to address the issues that affect their respective communities. While governments still play the dominant role in resolving societal challenges by means of management and public policy, non-governmental organisations (NGOs) like volunteer or charity groups are playing an increasingly active role in aiding governments whenever sufficient time, resources or human capital might not be readily available. Finally, with the spread of neoliberalism and the free market, it is becoming more and more common for governments to outsource responsibility for confronting certain societal challenges to private sector companies, effectively placing such issues in the hands of the community and merging them into the local economy. Societal challenges can be handled by any of these

three actors separately or by all three of them together. One example of the division of a single societal challenge among these three actors is that of providing healthcare, as most countries offer their citizens the options of either public or private sector services. Additionally, and particularly in times of crisis or humanitarian disaster, when the established systems of healthcare might be unable to cope with the gravity of the problems, politically unaffiliated non-profits like Doctors Without Borders contribute their services to help overcome these societal challenges.

1.3. First principles thinking and societal challenges

While it may be the role of the government, a corporation or a volunteer group to confront a given societal challenge by implementing solutions, one does not have to be a politician, a businessperson or a member of any organisation in order to produce innovative solutions. In fact, there is no predetermined profile for an effective first principles thinker. Many people already practise first principles thinking in their daily lives, often times subconsciously applying certain elements of the methodology to overcome personal or professional problems. Moreover, many existing solutions to current challenges—like the innovation of cultured meat in response to increases in global consumption levels[5] or that of drip irrigation in areas struggling with water scarcity[6]—are traceable to first principles thinking. Thus, to become such a problem-solver yourself, all you need is a dedicated commitment to a challenge you feel passionate about and a willingness to approach it in ways that might not reflect any of your previously held beliefs or assumptions. As you work through the steps of first principles thinking, you might even discover that your new approaches begin to take a direction that contradicts or undermines your previous views. Though this may at first seem alarming or even discouraging, it is actually a sign of the effective use of first principles, as the effective first principles thinker values pragmatism and originality over ideology and conformity.

At this point, it is time for you to think of a societal challenge you feel particularly passionate about, as it will be the subject of your exercises with first principles thinking throughout this manual. As stated above, this challenge has almost no limiting criteria: it can be local or international, economic or environmental, to be resolved by the public or private sector. What is most important is that you are committed to its resolution and unafraid to question your existing beliefs about it. For demonstrative purposes, this manual will use the challenge of ending freshwater shortage in Cape Town, South Africa in order to illustrate each of the seven steps of the first principles thinking method. After completing this exercise, we will go on to discuss how this method compares to and differs from other problem-solving techniques. Finally, we will conclude with a review of what we have learned as well as a few remarks about the limitations and implementation of first principles thinking.

PART 2 - FIRST PRINCIPLES THINKING IN STEPS

While societal problem-solving is often seen as a creative process that should not be overly confined by rules and procedures, first principles thinking is praised exactly for the fact that it embraces certain steps that direct your creative thinking. It is a systematic approach to generating ideas after all. The first principles thinking method, as we knew it before the introduction of this manual, typically dictates you to identify your assumptions, break down your challenge into its fundamental principles and create new solutions from scratch. Previous articles on the method have not gone much further than simply listing these action steps, which leaves much open to the intuition and interpretation of the applicant. Some aspiring first principles thinkers appreciate this more than others.

For those who would like some more guidance, we have sought to provide additional procedures and insights to consider when following these steps. Not only have we expanded each existing step, we have also added two additional steps that we feel are essential in the context of tackling a challenge that is societal in nature, such as bolstering the political attractiveness of a solution. This increases the chance for your ideas to be considered and implemented, which is probably the ultimate goal of this exercise.

As with any guidance, you are free to follow along to the extent that works best for you: meticulously or haphazardly. What we do recommend, however, is to read through the step before applying it yourself, as some insights are shared in the example challenge of water scarcity in Cape Town. Whenever you find yourself spending too much time or energy on a certain step, simply try to move on with what you have so that you can enjoy the benefits of the flow. This is not to say that you should not take breaks, as pauses can actually stimulate your creative thinking that takes place subconsciously.

2.1. Step I: Identify your objective

Whether you are consulting this manual with a specific societal challenge in mind or simply curious about the workings of first principles thinking, you should know for what challenges the method is most appropriate. As was alluded to in the introduction, it is suitable for a wide range of societal challenges, with different scopes and localities. However, we found that first principles thinking leads to more targeted and actionable solutions when applied to challenges that are concrete and demarcated to a specific territory. The more complex and multifaceted the challenge, the more likely you are to get lost in the process to follow, as wicked problems

often require multiple solutions and therefore many avenues for you to embark on. In other words, we advise you to embark on sub-challenges such as reducing air pollution in a particular city as opposed to reducing global climate change altogether. Indeed, the former challenge is still intimidating but already much more manageable than the latter.

What challenge you pick, however, is entirely up to you. What is a challenge for one is a blessing to the other. The legalisation of abortion in Nicaragua might, for example, be a problem for religious practitioners and a blessing for women experiencing economic hardship. You furthermore do not need extensive knowledge about a challenge to make a meaningful contribution since your knowledge and background can assist you in generating ideas that are either very much in line with the situation or completely new. In other words, select a challenge that you care about.

2.1.1. Not-SMART objectives

Once you have identified a societal challenge that is concrete and specific to a certain territory, you need to transform it into a concrete objective. As American inventor Charles Kettering accurately said, “a problem/objective well-stated is a problem half-solved”.[7] To do so we invite you to literally visualise and describe a situation in which the problem does not exist or is effectively dealt with. Visualisation will not only naturally guide the next steps, but also ignite your creative engine in a way that is practical and result-oriented.

Your intuition might tell you that your objective needs to be SMART (specific, measurable, attainable, realistic, timely). Instead, we ask you to only make it specific. This means that the objective needs to spell out exactly what needs to be improved, for whom and in what geographic location; but not more than this as overspecification could direct you into a traditional thinking pattern and limit the scope of possible solutions.

While measurability is important, it does not need to be addressed here because this will be done in a later stage. Furthermore, the objective does by no means need to be attainable or realistic because that would by definition undermine progress and innovation. Imagine if Edison and Swan, or anyone, had found it unattainable to harness electricity for longer periods of time, would light bulbs have ever been invented and changed the way we live? Instead, we actually encourage you to be “unrealistically” ambitious as long as your challenge remains specific to a locality. In an optimal exercise of first principles thinking there would be no time constraints in order to allow you to maximise the scope of solutions. However, in most real-life applications you will find that time constraints need to be taken into account and may actually stimulate creativity out of necessity. In other words, feel free to attach a deadline to your objective.

Lastly, when formulating your objective, make sure that you start with a verb such as increase, reduce, ensure, maintain, realise, etc. This does not only specify the necessity for action to change (or not change) the status quo, but also its direction, scope and ambition. This will help you make choices in the steps to follow.

2.1.2. Example

If we were to transform our challenge of freshwater shortage in Cape Town, it would be something along the lines of:

- Ensure sufficient access to fresh water for residents of Cape Town (by this date).

Can you visualise residents in Cape Town having enough running water in their taps and showers? It is specific because it outlines the need for action and its direction (ensure), because it specifies what needs to be improved (access to fresh water), and because it contains a concrete target group (residents of Cape Town). Indeed, measurability is lacking because 'sufficient' is not specified in units, such as litres of water per resident. This is intentional because accepting the assumption that a person needs, for example, 100 litres of water per day constrains your thinking and innovative capacity. Instead, such assumptions will be questioned later on. Is it attainable and realistic? Who knows at this stage? This highly depends on the solutions that we generate. In this case it might be natural to attach a deadline to the objective, for example 'Day Zero', which would be the date that municipal water supplies have to be switched off and residents have to queue for their daily ration of water based on projections of current water demand, reserves and incoming rain. In 2018, this was projected to be April 12.[8]

2.1.3. Your turn

Now it is your turn to select a challenge you care about and transform it into an objective. Remember that it needs to start with a verb and capture what needs to be improved, for whom and in which locality, possibly with a deadline, without demarcating it further than this. Feel free to use the box below to state your objective:

2.2. Step II: List your obstacles

As with any goal, there are always obstacles in the way. Once you have identified your objective, you need to list the obstacles in the path of the objective. In other words, what prevents the objective from being achieved? Again, try to visualise the objective and simply list whatever comes to mind intuitively or with the aid of your search engine. What helps is asking the question: what hinders this objective from not being achieved (yet), or what are the causes? Identifying possible obstacles is important because, as Roman emperor Marcus Aurelius accurately explains, what stands in the way becomes the way [to achieve your goals].[9] In other words, the greatest achievements wouldn't have been accomplished without obstacles guiding the way; so we need to embrace them rather than be fearful of them.

Once you have an exhaustive list of obstacles, you need to reduce it. We have identified two different approaches to do so, depending on the ambition of your objective. The first we call 'reduction through conditioning', which is suitable for when your aim is to resolve a societal challenge in its entirety, as highlighted by your objective starting with a verb such as ensure, realise, complete, eradicate, etc. The second one we call 'reduction through expertise', which is suitable for when you wish to use your personal background and (lack of) expertise to make a meaningful contribution that is likely to only partially resolve a societal challenge, as highlighted by your objective starting with a verb such as increase, reduce, mitigate, etc.

2.2.1. Reduction through conditioning

The first approach of reduction through conditioning asks you to consider the conditional and/or implicational relationship between each obstacle and the objective. In other words, you should take on all obstacles that, when tackled, are individually necessary and (jointly) sufficient to achieve your objective. An obstacle is individually necessary when the objective cannot be achieved without this obstacle being overcome. Physical inactivity, for example, is an obstacle that is paramount to eradicate child obesity in the city of Memphis in the United States. However, tackling inactivity is probably not sufficient to achieve this objective entirely, so more obstacles need to be considered, such as diet but also genetics and psychological factors. It is likely that when all these obstacles are overcome effectively that child obesity can be eradicated entirely. In other words, these obstacles are likely to be jointly sufficient to achieve the objective and no further obstacles need to be considered. You find that sometimes you need to address just one obstacle whereas at other times you need to address multiple. Sometimes, however, it may not be obvious which obstacles are individually necessary and

(jointly) sufficient. In such cases you need to make an educated guess, and if you are still unsure, possibly include additional obstacles to be on the safe side.

If this is too technical, just ask yourself which obstacles undermine the achievement of your objective the most. If your objective is sufficiently specified, you should end up with no more than four obstacles. Selecting obstacles through this approach not only helps you to stay focused on what really matters, but it also keeps this first principles thinking exercise manageable. However, if the achievement of your objective requires more obstacles to be tackled, for example to eradicate hunger in the city of Pagak in South Sudan, you have no choice but to list them all. In this case the obstacles could include a poverty trap, lack of investment in agriculture, unstable markets, climate and weather as well as war and displacement.

2.2.2. Reduction through expertise

The second approach of reduction through expertise asks you to consider the type of obstacles as well as your personal background and/or expertise. You probably know that, in essence, an obstacle is an object, thing, action or situation that undermines the achievement of an objective. In our view there are roughly two categories of obstacles, tangible and intangible, with various types within each category. Tangible obstacles are those that are physically, economically, biologically or militarily present in the world and can be touched or felt. Physical ones prevent mobility, such as vault doors being an obstacle to reach valuable items; economic ones prevent opportunities for development, such as a lack of money being an obstacle to receive an education; biological ones prevent human agency, such as blindness being an obstacle to perform everyday tasks; and military ones physically prevent opponents from undermining a certain territory, such as fortifications being an obstacle to plunder or annex a country.

Intangible obstacles, on the other hand, are those that are socially, psychologically, culturally, politically or technologically present in the world and are unable to be felt by touch. Social ones prevent entities with certain characteristics from exercising full agency, such as gender stereotypes being an obstacle for boys to openly play with dolls; psychological ones prevent fruitful human interaction, such as shyness being an obstacle to forge social relations; technological ones prevent progressive or reactionist shifts, such as the technological development of Artificial Intelligence not yet being advanced enough to achieve immortality; cultural ones prevent positive and meaningful interaction between particular people or societies, such as not speaking a certain language or holding different values being an obstacle

for building a life in a foreign country; and political/legal ones prevent the prioritisation of a societal composition, such as tax laws being an obstacle for companies to maximise profit.

2.2.2.1. Familiar obstacles

Once you have established the type of each obstacle, you need to determine which types you are knowledgeable about and/or which not. This can guide you to select obstacles that either very well match your background, or not at all. If you are knowledgeable about engineering, you may feel inclined to select physical obstacles, or if you are knowledgeable about psychology, you may want to address psychological obstacles. If you are indeed knowledgeable about psychology and it would be your objective to reintegrate former child soldiers used by the Lord's Resistance Army in Northern Uganda into society, you may, for example, emphasise psychological obstacles, such as overcoming PTSD, major depression and/or pathological anxiety.

2.2.2.2. Unfamiliar obstacles

At the same time, it can be very fruitful to take up obstacles that you feel unfamiliar with. If you are knowledgeable about technology, for example, you may want to address cultural obstacles because it would mean that you can approach them through a unique lens that both introduces unique technology-related insights and precludes assumptions that are widely accepted within the cultural community from influencing your creative process. This can yield very original solutions. If you do not want to go through the trouble of labelling each obstacle, you could also simply pick the obstacles that speak to you the most or least.

The reduction through conditioning and expertise should be seen as directories that allow you to make a conscious choice about which obstacles you take on; whether you follow or ignore it is up to you. Whatever approach you embrace and whatever obstacles you pick, you are likely to make a unique contribution. Lastly, we would like to emphasise that you should not be hesitant to include obstacles that may seem outside of your control, such as natural disasters and physical limitations. On the contrary, it is the seemingly insurmountable obstacles that first principles thinking is suitable for. You will be surprised what solutions you come up with once you maintain an open mind and abandon your assumptions.

2.2.3. Example

To ensure sufficient fresh water for residents of Cape Town, there are many obstacles that may come to mind, ranging from overconsumption of water to climate change. Because our objective starts with the verb ‘ensure’ and because we want to illustrate the power of the first

principles thinking method to come up with a wide range of solutions, it is natural to adopt the first approach to reduce the number of obstacles by way of conditioning. Because it is not immediately obvious which obstacles are individually necessary and (jointly) sufficient, we intuitively selected the following three obstacles that appear to undermine the achievement of our objective the most:

- There being insufficient rainfall.
- Water reserves being insufficient.
- Residents over-consuming water.

If you visualise these obstacles as non-existent or effectively being overcome you probably see scenes of pouring rain, filled water reserves and conscious water consumption. You would be quite confident that residents of Cape Town would have sufficient fresh water, which makes a good case for these obstacles being jointly sufficient. Indeed, to achieve such a sizeable objective, we had to pick obstacles that we may intuitively feel are difficult, if not impossible, to influence, such as the amount of rainfall.

To briefly illustrate, if we were to employ reduction by expertise, we would have picked different obstacles. Over-consumption of water is somewhat psychological because it is partly about being conscious about one's consumption, somewhat physical because the water is accessible to be over-consumed, and somewhat economic because the price of water (and therefore its demand) does apparently not run parallel to its availability. This labelling exercise may already inspire some (avenues for) solutions and we encourage you to write them down right away so that you do not waste your creative energy on trying to remember it later on. Since we, the authors, are both knowledgeable about public policy and have a solid understanding of economics, this obstacle would indeed be interesting for us to tackle because it has economic as well as more 'foreign' (psychological/ physical) aspects. The other two obstacles are more related to ecology and physics.

2.2.4. Your turn

Now it is your turn to identify and pick the obstacles that you will embark on in the steps to follow. Remember that you first need to make an exhaustive list and then reduce it either by way of conditioning or expertise. Your ambition (as highlighted by the verb in your objective statement) might help you in this effort. Also, it does not matter whether the obstacles fall seemingly within or outside your scope of influence as long as they undermine your objective and you limit the number to four whenever possible to keep things manageable for yourself in the next steps. Feel free to use the box below to list your obstacles of choice:

2.3. Step III: Question your assumptions

Most of the time obstacles are barriers built within the mind. Especially when it comes to societal challenges that are persistent and/or wicked, one often starts to accept that they can indeed not be overcome at all. A Kung Fu school in San Francisco describes this in the following way:

> As time passes, new layers are added to the wall that makes you unreceptive to new solutions. The bigger you allow the problem to grow, the bigger the barrier will be. Oftentimes, after failing to tackle a problem for a length of time, you forget what the essence of the problem ever was, but the barrier still lingers. The wall is reinforced by other issues that result from never resolving the first problem. It becomes a compounding situation and soon the barrier is so enormous that it seems insurmountable.[10]

In the context of this manual, such problems are obstacles and these layers are assumptions. Indeed, any obstacle is undoubtedly tainted by assumptions: these things that we accept as true or as certain to happen, often without much proof. Not only is the mere perception of something being an obstacle an assumption itself, it is very likely that this assumption, in turn, is based on a number of underlying assumptions.

This step seeks to uncover and critically question the assumptions of each obstacle so that we can liberate ourselves from any mental bias that may constrain our efforts to discover new solutions. Imagine if people like Dorothy Height or Martin Luther King Junior, alongside many others, accepted the assumption that people are not born equal, would they have ever fought for social/racial justice and successfully reduced segregation in the United States?

2.3.1. Socratic questioning

To identify the assumptions that constitute an obstacle you need to temporarily embrace the assumption that everything you think you know about the obstacle is untrue. Once you have this mentality you can start to critically challenge what you think you know through so-called '*Socratic questioning'* or 'expressing *Cartesian doubt*'.

This truth-finding method, embraced by Socrates and Descartes, encourages you to doubt everything you could possibly doubt by asking questions in a disciplined, rigorous and thoughtful manner so that you can reveal underlying assumptions logically, question their validity, correct misconceptions, identify fundamental truths and construct reliable knowledge.[11] The key distinction between Socratic questioning and normal discussion is that the former seeks to draw out, what are called, *first principles* in a systematic manner.[12]

According to a webpage of the University of Michigan on creative thinking, there are roughly six types of Socratic questions,[13] of which one explicitly targets assumptions. To identify and question the assumptions about your obstacles, you could ask questions such as: Why do we think that? Is this really true? Are we absolutely sure this is true? What is taken for granted here? What are the underlying assumptions? What components does this object comprise of? If … is true, how can … be true? What evidence/sources do we have for this? How can we verify or disprove it? What if this is wrong? What is another way of looking at it? What could we assume instead? What is a counterargument for ...? What if I thought the opposite?[ii]

Such rigorous questioning helps you to clarify your thinking, explain the origins of your ideas, challenge assumptions, look for evidence, consider alternative perspectives, and examine consequences and implications.[14] In other words, it helps you to dig deeper and get closer to the truthful core of your obstacles, which is what we call *first principles*.

2.3.2. Socratic questioning in groups

Your insights within a certain field may guide you where to look for assumptions and what questions to ask. However, for this to work effectively you will need to abandon the assumptions that you have come to accept, at least during the course of this exercise, to prevent you from getting stuck in traditional patterns of thought and therefore conventional solutions.

[ii] The questions listed here are partially adapted from the University of Michigan's (n.d.) "The Six Types of Socratic Questions" as well as Paul and Elder's (2006) "The Thinker's Guide to the Art of Socratic Questioning".

If you struggle with this step, for example because you selected obstacles that you are very much familiar with, it can be fruitful to do it together with someone else that is unfamiliar with the (type of) obstacles by entering into a 'Socratic dialogue'. In such a dialogue, your discussion partner is, or pretends to be, completely ignorant about the nature of your obstacles and asks you Socratic questions in a way that children question their parents. In other words, your discussion partner needs to be sceptical about every answer you give, and continue to ask follow-up questions: "Why, why, why?"

This is to stimulate critical thinking and to draw out your assumptions and possible misconceptions.[15] Whenever you find yourself answering "because I say so", you can be certain to have stumbled upon an unfounded assumption, in which case, try to stay objective and do not resort to self-defence. If you are a trained psychologist and selected psychological obstacles, you may, for example, want to enter into such a discussion with someone who has a background in maths so that this person can uncover and question the assumptions that are widely accepted within the psychological community.

You furthermore need to make sure that you record and/or write down your questions, answers and new insights. If you're doing this step in dialogue with someone else, it may be helpful to have a third person taking notes so that the flow of your discussion remains uninterrupted.

2.3.3. Example

If we were to break down the assumptions of the first two obstacles of there being insufficient rainfall and water reserves, we could ask Socratic questions such as: How many litres of water counts as sufficient rainfall? Who determines what is sufficient? How much rainfall do we have and need (to capture) per resident to overcome the dry summer months? How much water is captured by reserves? What counts as a water reserve? Do we even need water reserves? What if we work with what we have? Is any captured rainfall spilled? Where does uncaptured water go? What if we instead assume that there is sufficient rainfall? Is rainfall captured effectively? Do we actually need rain to get fresh water? What properties does rainfall consist of? Can these properties be found elsewhere?

With regard to the third obstacle of residents over-consuming water, we could ask Socratic questions such as: Why do we think residents over-consume water? On what evidence and metrics is this based? How much does each resident consume? What water consumption level is sustainable per resident? What would happen if there would be no water at all? Why do people over-consume water? Do we need to consume water at all? What is water used for, and are there alternatives? Which foods require a lot of water?

Indeed, we combined obstacles one and two because, as we started this exercise, we noticed that there was considerable overlap. This is completely fine as long as it stays clear to you. You furthermore might have noticed that measurability becomes important here. If we were to incorporate measurability in our objective statement, we wouldn't have allowed ourselves to question the assumptions that underlie the question of what actually constitutes sufficient rainfall, water reserves and water consumption; this would in turn limit the scope of possible solutions.

2.3.4. Your turn

Now it is your turn to critically question the assumptions that underlie each obstacle. Remember that you first need to abandon the assumptions that you have come to accept as true, after which you can start to engage in Socratic questioning, alone or with someone else, to look for evidence, consider alternative perspectives, and examine consequences and implications. Feel free to use the box below to list your lines of Socratic questioning:

2.4. Step IV: Uncover your first principles

Now that you have penetrated the assumptions regarding your obstacles of choice by asking Socratic questions, you need to try to answer them, if you have not done so already, so that you can get as close as possible to the core, or first principles, of each obstacle. What truly constitutes a first principle is not always evident, so we have outlined a few characteristics of those that are correct (first principles) and incorrect (false principles).

2.4.1. First principles

The existence of *first principles* is based on foundationalism, which asserts that there are fundamental self-evident first principles that cannot be deduced any further and serve as the basis of all objective knowledge, valid arguments and other truths. As stated earlier, Greek philosopher Aristotle defines a first principle as "the first basis from which a thing is known".

If you wish to prevent plastic pollution on the beaches and bird colonies of the Isles of Mull and May in Scotland, you may end up querying your search engine what constitutes a plastic and have Plastics Europe tell you that plastics are derived from materials such as cellulose, coal, natural gas, salt and, most importantly, crude oil. In turn, you would find that each of these materials are a mixture of various other compounds, of which most importantly, naphtha, which comprises of hydrocarbon chains, which in turn comprises entirely of hydrogen and carbon molecules.[16] Indeed, we have identified a first principle, namely that, 'hydrogen and carbon molecules are important components of plastics'.

Indeed, sometimes you need to think like a scientist and, as a layperson, some questions may seem daunting to answer. If your knowledge indeed falls short, a simple query in your search engine will likely work miracles, as the example above illustrates. You will find that the identification of first principles can be more straightforward at other times, for example when asking "what plastic goods are the most common polluters in this particular case?" Again, a quick search will direct you to news articles that mention (and visually show) single-use bottles, bags and cotton buds.[17] [18] [19]

However, your intuition, common knowledge and search engine can only get you so far. Certain questions, especially if they concern a demarcated territory, do not have a precise answer ready, so you will have to rely on an educated guess or adopt a higher level of abstraction. "What are the main sources of plastic pollution in this particular case?", for example, is not easily verifiable online so we looked for a less demarcated answer, and found that 80% of all plastic pollution that strands on coastal areas comes from land-based sources outside Europe, such as landfills and rivers.[20] This is pretty much the most precise answer we can get to within a timeframe and scope of effort that we find reasonable at this moment. As such, we stop here and consider this another first principle since it seems to come from a reliable source that supports claims with scientific evidence. However, this also means that our solutions resulting from this first principle are likely to be at the same level of abstraction and thus less targeted to the specific problem at hand. If you wish to reach first principles (and solutions) that are more targeted to your specific case, you could conduct deeper research, for example by contacting oceanographers with the request to map the ocean circulation streams that pass both landfills as well as the Isles of Mull and May. Lastly, whenever you seek to identify first principles, be cautious not to engage in '*greedy reductionism*', which occurs when you underestimate complexities and skip important layers of inference in a rush to arrive at first principles as soon as possible.[21]

2.4.2. False principles

Sometimes you may feel that you have identified a first principle while it is actually a *false principle*, as we choose to call it. False principles are based on beliefs and assumptions that are grounded in normativity such as political ideologies and religious beliefs, among others. They are often used as norms and values to evaluate or judge objects, behaviour and outcomes as either good, desirable or permissible, or bad, undesirable or impermissible. English philosopher John Locke, for example, embraced false principles based on moral duties from which natural rights to property and life could be derived. He said: “we have a duty not to kill so we have a natural right to life”, “we have a duty not to oppress others so we have a right to liberty” and “we have a duty not to steal so we have a natural right to property”.[22] In the latter example, the clause “having a duty not to steal” is a false principle, from which unscientific new knowledge is built, namely “having a natural right to property”, as highlighted by the coordinating conjunction “therefore”.

Indeed, what makes these false is that they are subjective and therefore debatable. Some may, for example, argue that caregivers who experience financial hardship actually do have a duty to steal if they would not be able to feed their babies otherwise; what is a false principle for one is not necessarily a false principle for the other, hence the label of being false. Another characteristic of false principles is that they are not fundamental because they rest on other beliefs and assumptions, in this case, that we have moral duties. You can establish this by asking: “why, why, why?” “Why do we have a duty not to steal?” “Because it is our moral duty.” “Why is it our moral duty?” “Because we are humans, not animals, with a consciousness.” “Why does having a consciousness entail having moral duties?” Etcetera. Indeed, you are unlikely to reach objective truths. Moreover, one could also turn things around and say “we have a right to property and therefore a duty (not) to steal”; what was new knowledge is now the false principle itself. Any new knowledge that is based on such false principles is likely to be subjective as well. In other words, everything that is not a law of nature is just a shared belief.

2.4.3. Example

If we were to answer the questions posed in the previous step regarding water shortage in Cape Town, we would, for example, find that:

- A person needs water because cells, organs and tissues use it to help regulate temperature and maintain other bodily functions.[23] A person needs about 1.9 litres (64 ounces) of fluid intake per day. Cape Town receives about 154-788 mm of rain per

year.[24] Most of it gets absorbed by the soil or escapes as vapour to the atmosphere during the day.[25]

- Water consists of two hydrogen atoms and one oxygen atom.[26] These properties can also be found in the atmosphere.[27]
- 50 litres (13 gallons) of water consumption per resident per day is sustainable.[28] Residents' daily water consumption is about 169 litres.[29] [30] Water is used for showering, cooking, flushing and swimming. Used water ends up in sewers. People over-consume water because they are unaware or do not care.
- Water is best absorbed by the body in the morning. Rice requires relatively more water than other foods.[31]

These fact-based findings are what we call first principles. Indeed, they are not always simplified to the most atomic level, but you get the intuition. What is important is that you go a few levels deeper than others and answer your questions in a way that is supported by science. Again, you might also have noticed that we did not answer all questions; we simply answered whatever we could easily find an answer to, as to not disrupt the flow of this exercise.

2.4.4. Your turn

Now it is your turn to answer your Socratic questions and discover your first principles. Remember that you can do so by an educated guess or with the aid of your search engine as long as the answers are based on science and deduced as much as is reasonably possible without pondering too much on a single matter. Feel free to use the box below to list first principles:

2.5. Step V: Come up with new ideas

Now that you have identified some first principles you need to turn them into innovative ideas. Remember that this method is typically used to reveal underlying assumptions logically, question their validity, correct misconceptions, identify fundamental truths (first principles) and construct reliable knowledge.[32] When it comes to societal problem-solving, however, instead of building new knowledge you build new ideas. To do this you need to ask open questions that link the first principles with the obstacles that you selected.

2.5.1. "How-questions"

A good starting point is to ask open-ended "how-questions" because it encourages your creative mind to offer solutions rather than problems. If we were to ask you "What do you dislike about this manual?", you might reply "It is too lengthy". Indeed, this identifies a problem, but not a path to solving it. Alternatively, we could ask you "How could we improve this manual?", and you might reply "Reduce the explanations and examples to bullet-points because I want to start tackling societal challenges as soon as possible". Indeed, such questions are more likely to spark solutions because they encourage you to think beyond the problem itself.

Some example questions that are generally applicable are: How can we do this more efficiently? How can we capture more volume? How can we do this cheaper? How can we extract these components from elsewhere? How can we reuse this? How can we prevent this from happening? How can we make people stop doing this? How can we reduce this? How can we substitute that? "How can we", "how might we" and "how could we" are your go-to starting points for each question. To the same effect, you might also ask certain what-questions, such as "What can we do to improve this?", which is basically the same as asking "How can we improve this?" What matters is that they are open-ended and encourage you to think about solutions rather than problems. Again, it can be helpful to visualise your objective statement and/or ideal situation when doing so.

By now you may have come up with some promising ideas already. It is important to briefly write down every possible idea that comes to mind, even those that may exist already, and especially those that seem unorthodox, radical or impossible at first. Doing so is important not only because it empties your mind and creates space for new solutions to arise but also because different solutions might complement each other through being synthesised into even more innovative, viable, comprehensive ideas. It can actually be quite fruitful to actively think

about applying each idea to questions and solutions pertaining to different obstacles to make the ideas even more innovative and comprehensive.

2.5.2. More questions

However, as you have experienced during the identification of first principles, sometimes you need to ask additional questions about the answers to your initial questions. If your objective is that Rohingya refugees are able to re-establish livelihoods in the Rakhine State of Myanmar, if you selected the obstacle that they are likely to be killed upon their return and if you found a first principle that this will be done by the Tatmadaw (the armed forces of Myanmar) with the aid of advanced weapons supplied by Russia,[33] you might ask yourself "How can we stop the weapon supply from Russia to Myanmar?" This is a rather broad question that may inspire a multitude of ideas among which, for example, "Make the Tatmadaw not want their weapons". Indeed, this idea is still quite broad and as such requires follow-up "how-questions" to get to ideas that are more actionable. You could ask "How can we make that the Tatmadaw does not want the weapons anymore?" and come up with the idea "To spread 'fake news' saying that the weapons are unsafe for their users due to design flaws".

Depending on the level of abstraction of your first principles as well as how targeted you wish your solutions to be, you could ask even more questions, such as "What news sources does the Tatmadaw read and find credible?" and find that this is would be 'The Myawady Daily', which is a military-run daily newspaper.[34] "How can we encourage them to publish this?" "What kind of stories do they publish?" "What are their sources?" "Which of them can be (monetarily) persuaded to supply such news?" Indeed, this exercise of asking and answering questions is analogous to the search for first principles through Socratic questioning, which should lead to ideas that are more concrete and actionable. Again, the more accurate and scientifically-founded your first principles are, the more targeted your solutions are likely to be.

While the ideas, such as spreading fake news, might not always be completely new, they are likely to be unthought of in the context of tackling your societal challenge of choice. It is unlikely that we would have come up with such a solution without asking "how-questions" first. Again, the solutions that you come up with are likely to depend on whether you selected the obstacles through conditioning or expertise as well as your background and past experiences.

You are furthermore likely to find yourself not answering all questions, which is completely understandable. If this is the case because some of them simply do not spark any ideas, don't dwell on them for too long and just move on to another question. On the other hand, if you cannot answer some questions because they require highly technical or scientific knowledge, asking the questions can be a contribution in itself because other people might have the

answer. What is important is to ask multiple questions because the more questions you ask, the more (avenues towards) solutions you are likely to think of. Likewise, if someone else with a completely different background conducted this exercise, you may have some answers to their questions. It is not only fruitful to examine the solutions of others for this reason but also because you might identify complementarity between your ideas and those of others.

2.5.3. Example

If we were to link first principles with the obstacles in the way of ensuring sufficient access to fresh water for residents of Cape Town, we would ask "how-questions" such as:

- How can we prevent moisture from escaping into the soil? How can we capture the vapor? How can we capture rain more effectively? How can we get water from elsewhere to Cape Town?

These questions may inspire ideas such as (1) placing a system of funnels, strainers and pipes under the soil to collect rainwater; (2) installing water quality meters and/or purifiers at major water collection points such as gutters, drains and sewers to repurpose clean water; (3) putting a funnel-like cover over water reserves to reduce evaporation; (4) dragging icebergs to Cape Town;[iii] and (5) having fire helicopters supply water to off-road places.

- How can we extract water properties from the atmosphere?

These questions may inspire ideas such as creating atmospheric water generators to extract water from the air and attaching them to buildings to cater for their occupants' water needs.

- How can we make people more aware of their own personal roles in conserving water? How can showering, cooking, flushing and swimming take place with less water? How can water be reused?

These questions may inspire ideas such as (1) reducing water pressure in showers; (2) measuring and publishing the water consumption of each household; and (3) shutting off nearly all water supply for one day to let residents experience the possible future.

- How can we make people drink water in the mornings instead? How can we discourage people from making rice? Are there more efficient ways to make rice?

[iii] This idea was actually developed by Nick Sloane, a salvage professional from South Africa. For more information visit https://businesstech.co.za/news/business/327999/a-uae-businessman-wants-to-drag-an-iceberg-to-south-africa/.

These questions may inspire ideas such as (1) having garbage trucks tag along mobile water tanks to supply free drinking water in the mornings while they go there to pick up trash anyways; and (2) stop selling or putting awareness stickers on water-intensive foods in supermarkets.

Indeed, not all questions are answered because some did not spark any ideas while others, such as “How can we extract water properties from the atmosphere?”, require highly technical knowledge. Of course, we could ask further questions to reach a deepened level of abstraction. Regarding the idea of putting awareness stickers on water-intensive foods in supermarkets, we could have asked ourselves “What should the stickers look like to effectively discourage consumption?” and remember a study that concluded that having a picture of an angry baby face at openly accessible public toilets that ask for a small fee effectively nudges users to pay. This might inspire the idea for the stickers to include a picture of an angry baby face or something similar. If we were to apply each idea to questions and possible solutions pertaining to different obstacles, the sticker idea might, for example, inspire the idea to place road signs at major water collection points saying that you should not dump trash, as it may contaminate water reserves.

2.5.4. Your turn

Now it’s your turn to pose “how-questions” linking the first principles to your obstacles in order to come up with new ideas. Remember that you can start your first questions with “How can we ...” and ask follow-up questions to make your ideas more actionable. Make sure that you write down all the ideas that come to mind and try to merge them with different questions and ideas. Feel free to use the box below to list your “how-questions” and ideas:

2.6. Step VI: Refine your ideas

The first principles thinking method, as we knew it before the introduction of this manual, typically strands once ideas are generated because the approval and support of other parties, for example political decision-makers and public authorities, can be difficult to secure. This is often the case because little thought goes into what will happen after the ideas are generated and how they will be evaluated by others.[35] Innovative solutions inherently entail (political) risks and costs, and other parties might be subscribers to more traditional approaches to problem-solving.

In informal contexts and small organisations, the review process is often a simple matter of someone reading through a number of ideas and selecting those that he/she believes will work best.[36] In more formal contexts and large organisations, a structured evaluation often takes place (1) to identify ideas with the most potential by subjecting ideas to rigorous cost-benefit/SWOT analyses and other evaluation criteria; (2) to review multiple complex ideas by people with the appropriate expertise in a resource-efficient manner; and (3) to defend an idea before senior management, stakeholders and financial officers who may need to approve and/or help implement the idea.[37]

Because the informal review is rather vague, subjective and often tainted by traditional beliefs and assumptions, the review is likely to fail to recognise the innovative potential of some ideas, resulting in the rejection of the most potentially innovative ideas in favour of less innovative ones.[38] In other words, there needs to be some systematic process when reviewing ideas. The formal review, on the other hand, is likely to butcher your ideas exactly because of its systematic nature, which is unsurprising given the fact that, until now, you have not consolidated the traditionally-used evaluation criteria into your ideas.

As such, we propose an additional step that, firstly, promotes the use of evaluation criteria that are typically considered when assessing ideas to tackle societal challenges, and secondly, ensures that your ideas take the evaluation criteria into account without reducing the space for innovation. In fact, this step treats the evaluation criteria as an opportunity to enhance your ideas. In turn, this makes it more likely that your solutions receive the necessary approval and/or support to actually end up on the implementation table.

2.6.1. Quick pass-fail evaluation

By now you may have come up with a large number of new ideas. Because it could take a long time to evaluate each of them thoroughly, we invite you to continue with those that you feel strongly about. It is up to you on what basis you will reject the ideas; intuitively or on the basis

of basic requirements that are most relevant to the context in which your ideas are to be implemented. This could be monetary costs, timeframe, impact, practical viability, etc. While eliminating ideas, do keep in mind that the next step seeks to refine your ideas. As such, you might want to pass very innovative ideas that do not initially meet your budget criterion because you might find a way to implement them at lower costs. Depending on the potential of your ideas as well as your commitment, you can pass up to a million ideas. We do, nevertheless, recommend you to pass at least five ideas to decrease the chance for all solutions being rejected.

2.6.2. Set your evaluation criteria

Now that you have narrowed down your ideas to a manageable volume, it is time to subject them to thorough evaluation and refinement. Because the contextual specifics of societal challenges can vary greatly, it is important that you determine evaluation criteria that fit your situation. If you are the sole evaluator, decision-maker and implementer of your ideas, you can set your criteria according to your preferences and view of the situation. If you engage in first principles thinking on behalf of a client or superior, you might want to consider (or better yet, ask about) their preferences and views on the situation. If a challenge requires a solution urgently and your client has unlimited resources, effectiveness and timely implementation may be more important than implementation costs, for example.

We identified eight evaluation criteria that are virtually always relevant to consider when tackling societal challenges, including innovativeness, effectiveness, realisability, monetary costs, harmful effects, political attractiveness, urgency and adaptability. You are, nevertheless, free to add and remove evaluation criteria depending on the challenge at hand. Other criteria might, for example, be inclusiveness, sustainability and internationality.

2.6.3. Socratic questioning

Now that you have set the evaluation criteria you, again, engage in Socratic questioning to both determine and enhance the performance of your ideas in relation to each criterion. To refresh your memory, this type of questioning requires you to doubt everything you could possibly doubt about your ideas by asking questions in a disciplined, rigorous and thoughtful manner so that you can reveal underlying assumptions logically, question their validity, correct misconceptions and flaws, identify fundamental truths (first principles), consider alternative perspectives, and enhance your ideas so that they can become fitting solutions.

To determine the true performance of your ideas in relation to each criterion, you could ask Socratic questions like you did in step III, such as “Why do we think that?”, “What could we

assume instead?" or "What are its individual components?" Then try to answer them intuitively like you did in step IV and you will stumble upon first principles. Once you have identified first principles, you can ask "how-questions" like you did in step V with the goal of enhancing your ideas, for example "How can we do this more efficiently?", "How can we extract these components from elsewhere?" or "How can we realise this without a particular component?"

Below we outline why we picked the eight evaluation criteria that are virtually always relevant to consider when tackling societal challenges through first principles thinking, and illustrate how you could subject them to Socratic questioning:

2.6.3.1. Innovativeness

To tackle (persistent) obstacles it is important that your ideas have not yet been implemented before in the context of your challenge or in the form that you propose. Because first principles thinking inspires all kinds of ideas, it is possible that you come up with ideas that have already been considered. To first determine and then enhance the performance of your ideas in relation to being truly innovative, you could subject it to Socratic questions that are similar to the following:

- Has the idea been introduced in the context of your challenge? Has the idea been introduced in the context of a distinctive challenge? Is it a significant improvement of an existing idea in the context of your challenge? What makes it innovative? What has been done elsewhere to similar challenges?
- How can we improve the application of an idea that exists in another context? How can we change the idea to make it more innovative? How can we improve the idea further? What technologies are available to complement the idea? What if someone said that the idea is only at half of its innovative potential? How can we make the idea less boring and more memorable?

2.6.3.2. Effectiveness

To factually tackle obstacles, it is important that your ideas are impactful. Because first principles thinking usually inspires new ideas whose effectiveness has not been verified before, you need to gauge their effectiveness yourself. To first determine and then enhance the performance of your ideas in relation to being truly impactful, you could subject them to Socratic questions that are similar to the following:

- Which obstacle(s) is it supposed to impact? In what ways does it overcome the obstacle? Does it overcome the entire obstacle? Why is it individually necessary to

overcome an obstacle? What other ideas do you have to tackle this obstacle? What proof do you have that, in combination with these other ideas, it can sufficiently overcome the obstacle? What solvability gaps does it leave?

- If this would be the only idea, how could we increase its impact so that it could individually overcome the obstacle? How can we increase its impact? What other ideas could we pick to jointly overcome the obstacle? How can we make that it impacts other obstacles as well? How can we use this and other ideas to fill the solvability gaps?

2.6.3.3. Realisability

To be able to tackle (persistent) obstacles it is important that your ideas are, or have the potential to become, realisable. Because first principles thinking is very much founded on science, you are likely to arrive at solutions that require technical expertise and/or technological competence. To first determine and then enhance the performance of your ideas in relation to being truly realisable, you could subject them to Socratic questions that are similar to the following:

- What is individually necessary and/or jointly sufficient to realise this idea? What aspects are available and easily realisable? Does the required technology and expertise exist? What is missing to realise the idea? What could frustrate implementation? What evidence is there?

- How can we acquire all the necessary pieces? Do we really need the missing pieces? Will the idea still work without these pieces? How can we create/ substitute/ work around what is missing to realise this idea? How can we merge these pieces to realise the idea?

2.6.3.4. Monetary costs

To tackle obstacles through solutions that are (traditionally) funded by taxes and/or public funds, it is important that the monetary costs of implementing your idea are proportional and cost-efficient. Because first principles thinking can generate unconventional ideas of various sizes that have not yet been implemented before, it is possible that some of them seem overly expensive to implement. To first determine and then enhance the performance of your ideas in relation to being truly cost-efficient, you could subject them to Socratic questions that are similar to the following:

- What are the monetary costs of components that are individually necessary and jointly sufficient for your idea to be effective? What are the costs of each sub-component?

How did you get to these costs? Who pays? Who benefits from the idea? Who would support the idea?

- How can we reduce the cost of each cost component? What alternative sources of finance are there? How can we make the costs more justifiable? How can we enlarge its scope of benefits? How can we spread the costs over different benefactors/ supporters? How can we make them excited to pay? What else can we offer them in return for their financial support? How can we turn the costs into a viable investment that recovers the costs later on? How can we design the idea so that it will actually generate money? How can we build a business case around the idea? How can we finance the idea without prescribing to public funds at all? How can we realise the idea without involving any money?

2.6.3.5. Harmful effects

To tackle obstacles without causing problems elsewhere, it is important that your ideas do not entail (too many) harmful effects. Because first principles thinking often generates new solutions of which their effects are not always fully known, it is possible that harmful effects arise. To first determine and then enhance the performance of your ideas in relation to entailing harmful effects, you could subject it to Socratic questions that are similar to the following:

- What/who will be affected? What/which will be negatively affected? What makes it negative? How sizable are the effects? What evidence do we have for this? Are the effects reversible/mitigatable?

- How can we avert the harm? How can we isolate/detach the obstacle from other areas that might experience harm? How can we mitigate the harm? How can we reverse the harm? How can we make the harm more manageable? How can we compensate the harm? How can we make benefactors of the idea compensate victims? How can we turn harm into benefits?

2.6.3.6. Political attractiveness

To tackle obstacles that political actors and/or public authorities carry responsibility for, it is important that your ideas are (politically) attractive and without much risk. Because first principles thinking is likely to generate ideas that are unconventional and morally questionable, and therefore risky, it is possible that certain actors and entities are hesitant to embrace your ideas. To first determine and then enhance the performance of your ideas in relation to being (politically) risky, you could subject them to Socratic questions that are similar to the following:

- Are the risks greater than potential benefits? Who are the responsible politicians and public authorities? How much risk are they typically willing to take? What was their consideration with regard to past risks that they took? What makes the idea risky? What makes it morally questionable? If the risks turn into realities, what are the repercussions? What exactly makes it a risk?

- How can we persuade the responsible entities? How can we make this idea less risky than other decisions they have taken? How can we frame the idea as being less risky and/or absolutely necessary? How can we mobilise benefactors to openly support the idea? How can we mitigate risks? How can we reduce the repercussions in case risks turn into realities? What if we thought of them as being opportunities rather than risks? How can we make the idea more attractive? How can we make the idea morally justifiable? How can blame be avoided/ mitigated/ spread in case of failure?

2.6.3.7. Urgency

To tackle societal challenges that cause irreversible damage in the (near) future, it is important that your ideas can be timely implemented. Because first principles thinking can generate various ideas with different timelines, it is possible that some of them may seem too slow. To first determine and then enhance the performance of your ideas in relation to being able to be timely implemented, you could subject them to Socratic questions that are similar to the following:

- What happens if the idea is not implemented? When is it too late to implement the idea? What is the earliest the idea could be implemented if we start now? When would the idea produce its intended effects? What actions need to be taken to implement the idea? Who needs to approve the idea?

- How can we accelerate implementation? How can we delay the negative effects of the challenge to buy more time? How can we skip/speed up each action? What can we do now to avoid irreversibility? What quick wins could we start with? How can we design the idea for it to become more easily implementable? How can we get all the necessary parties on board for the idea as quickly as possible? How much of the idea can we implement without the support/approval of other actors?

2.6.3.8. Adaptability

To continue to tackle societal challenges in a dynamic environment, it is important that your idea is adaptable to (sudden) changes and unintended consequences. Because first principles thinking can generate all sorts of ideas, it is possible that some are more flexible or rigid than

others. To first determine and then enhance the performance of your ideas in relation to being truly adaptable, you could subject them to Socratic questions that are similar to the following:

- Once the idea is implemented, is it flexible to changing situations? What are the rigid aspects of the idea? Can you always maintain control over the direction and outcomes once it is implemented? Who will be in charge of monitoring/ altering its implementation? How easy is it to take a decision to change the idea? Upon implementation, in what ways can you change it? What makes this idea adaptable? What makes it inflexible? If ... happens, can you change its shape, pace or outcome? Is it always adaptable? To what kinds of changes is it adaptable? Can you think of a situation where your idea is unable to be altered accordingly? What evidence can you give? Can you pause the idea once in motion? How long does it take to pull the plug?
- Once in motion, how can we pause the idea? How can we make the idea more adaptable? How can we make unadaptable aspects more adaptable? Or can we replace them? Can we reduce the steps/ time it takes to change/ stop the idea once implemented? How can we monitor the idea and forecast its course? How can we make the idea self-adjustable?

2.6.4. Example

If we were to evaluate the ideas generated to overcome the obstacles in the way of ensuring sufficient access to fresh water for residents of Cape Town, we would not only select the evaluation criteria of innovativeness, effectiveness, realisability, monetary costs, harmful effects, political attractiveness, urgency and adaptability, but also those of inclusiveness and sustainability because we find it important that, first, fresh water becomes available to all people regardless of their socioeconomic situation, and second, that the achievement of this objective does not occur at the expense of future water supply. For illustration purposes, we will only subject the idea of “having garbage trucks tag along mobile water tanks to supply free drinking water in the mornings while they go there to pick up trash anyways” to the relevant evaluation criteria.

With regard to the idea’s performance in relation to being ***innovative***, we found that mobile water tanks do exist[39] but not in combination with being pulled by garbage trucks. That’s innovative enough for now. With regard to ***effectiveness***, we feel that this idea alone cannot tackle the obstacles entirely, although it can significantly help achieve the overall objective because it could cater for drinking water needs. We could increase its effectiveness (and innovativeness) by attaching atmospheric water generators to the garbage trucks to extract water from the air. With regard to the idea being ***realisable***, we found that it is quite realisable

because all we would need to do is attach some sort of platform that can carry water storage containers and, if possible, atmospheric water generators to existing garbage trucks. To save weight (and thereby fuel), we could make the platform itself contain water. Also, if possible and cost-efficient, a part of the collected water could be converted into hydrogen as fuel for the truck. With regard to ***monetary costs***, the garbage truck already exists; an atmospheric water generator costs €500 to €2,000;[40] a 1,000 litre (264 gallons) water container costs about €40;[41] and a hydrogen generator is about €2,700.[42] Of course there are more costs involved but this serves as a quick overview. Also, the atmospheric water generator might not be cost-effective to install, unless it is co-sponsored by the producer. To reduce the costs we could have companies sponsor the initiative, and in return they could have their logo on the truck saying "this drinking water is sponsored by ..." Alternatively, we could install a price mechanism to trade (segregated) trash for drinking water, which also saves cleaning and eventually healthcare costs. We could furthermore set up a competition for students to develop this concept idea with little costs.

With regard to ***harmful effects***, we need to make sure that the water is not contaminated by trash and emissions, for example by installing water quality meters and/or purifiers. We should furthermore try to discourage people from stealing water as well as each other's trash, for example by having a maximum amount of water to give to each person every day. With regard to ***political attractiveness***, it seems quite attractive if it can be realised in a cost-efficient, effective and non-harmful way. We could furthermore have pictures of supportive (local) politicians on a truck, again saying something like "this water is brought to you by ..." With regard to ***urgency***, we feel that the basic necessities (truck + water container + water quality meter) can be implemented rather quickly if we encourage politicians/public authorities to support the idea and companies to fund this initiative. We could, for example, reach out to news outlets to get exposure for the call for support/funding since this is a hot topic. Extras can be added gradually when funds allow it. With regard to ***adaptability***, we could install procedures in case there is insufficient/unsafe water, or install the water quality meter in a way that when quality drops under a certain point, the water is not accessible. With regard to ***inclusiveness***, making sure water is delivered to informal settlements as well, we could adjust the number, route and/or timing of garbage trucks, or have fire helicopters supply water to remote places. With regard to ***sustainability***, making sure that this idea does not occur at the expense of future water supplies, garbage trucks could continue to collect and cleanse water during rainy periods in preparation for dryer seasons.

Indeed, the initial idea has evolved into a solution that takes into account various evaluation criteria that are likely to be important. To some questions we don't have solid answers;

however, asking them anyways is worthwhile because others might have answers or alternative ideas.

2.6.5. Your turn

Now it is your turn to pass/fail your ideas as well as to determine relevant evaluation criteria and ask Socratic questions to both determine and enhance the performance of your ideas in relation to each criterion. Remember to keep an open mind when identifying first principles and asking “how-questions”. Feel free to use the box below to list your evaluation criteria and ideas to enhance the ideas in relation to each criterion:

- Innovativeness:
- Effectiveness:
- Realisability:
- Monetary costs:
- Harmful effects:
- Political attractiveness:
- Urgency:
- Adaptability:
-
-

2.7. Step VII: Select your solutions

By now you should have a few promising solutions. But before you take each of them to the implementation table, you should determine which of them are most appropriate to achieve your objective. This, in turn, depends on whether you reduced your obstacles through conditioning or expertise in step II.

2.7.1. Selection through conditioning

In case your objective is to tackle the societal challenge in its entirety and you chose to select your obstacles through conditioning, you need to determine which solutions are individually necessary and/or jointly sufficient to overcome the obstacles that are, in turn, individually necessary and/or jointly sufficient to achieve your objective. In other words, see which obstacles you selected and which solutions have the potential to overcome them. In doing so, you should also take into account existing efforts and solutions.

If you find that the solutions do not have the potential to overcome all obstacles necessary to achieve your objective, even though you considered a number of (synergised) solution-combinations, you could focus on the gaps and, again, try to seek additional solutions through first principles thinking. In other words, you could start engaging in Socratic questioning, identify first principles, come up with new solutions and refine them according to your evaluation criteria. You could also ask someone else, preferably with a different background, to do this exercise and come up with complementary solutions.

2.7.2. Selection through expertise

In case it is your objective to contribute as much as possible to either increase or decrease the scope of any aspect related to your challenge with the aid of your personal background and expertise, you could rank each solution. To do so, you could intuitively allocate scores to each solution along the criteria. When it comes to innovativeness you could, for example, score your idea 0 points if it is not innovative and 2 if it is very innovative. The following matrix may be used:

IDEAS / CRITERIA	*Solution 1*	*Solution 2*	*Solution 3*	*Solution 4*
Is it innovative?	0	0	0	0
Is it effective?	0	0	0	0
Is it realisable?	0	0	0	0
Is it cost-efficient?	0	0	0	0
Is it unharmful?	0	0	0	0
Is it politically attractive?	0	0	0	0
Is it timely implementable?	0	0	0	0
Is it adaptable?	0	0	0	0
	0	0	0	0
TOTAL	0	0	0	0

By now you should have a good picture of the performance of each idea in relation to each evaluation criterion. Before picking solution(s) to bring to the implementation table, you should remember that such an evaluation matrix is a tool for making decisions and not a decision-making system. As such, we advise you not to simply pick the solution that has the highest total score, but instead consider which evaluation criteria are particularly important to you. If keeping costs low is important to you, you could emphasise solutions that score highly on cost-efficiency.

You will sometimes find yourself unable to confidentially allocate scores to certain ideas because you lack answers or details. However, this should not intimidate you because the lack of answers and presence of risk are inherent to innovation. Intuition can get you a long way.

2.7.3. Example

Because, in the case of water scarcity in Cape Town, we reduced the obstacles according to conditioning, we need to select solutions that are individually necessary and jointly sufficient to overcome the obstacles of there being insufficient rainfall, water reserves being insufficient, and residents over-consuming water. While the solution of garbage trucks carrying water tanks (possibly in combination with fire helicopters to reach remote areas) has the potential to accommodate the most basic water needs of residents in Cape Town and does play into the three obstacles, it is far from sufficient to overcome the obstacles completely.

This means we need to consider additional solutions. Because we did not refine other ideas for the sake of conciseness, this is suboptimal. For illustrative purposes we will take the plunge anyways. For the first obstacle of there being insufficient rainfall we could consider dragging icebergs to Cape Town and/or creating atmospheric water generators to extract water from the air and attaching them to buildings to cater for their occupants' water needs. For the second obstacle of water reserves being insufficient we could consider putting a funnel cover over water reserves to reduce evaporation. For the third obstacle of residents over-consuming water we could consider measuring and publishing the water consumption of each household, shutting off nearly all water supply for one day to let residents experience the possible future, and/or putting awareness stickers on water-intensive foods in supermarkets.

2.7.4. Your turn

Now it is your turn to select which solutions you will take to the implementation table. In case you reduced the obstacles through conditioning, remember that you should determine which solutions are individually necessary and/or jointly sufficient to overcome the selected obstacles (if not, scroll past the box below). Feel free to use the box below to list the solutions necessary to do so:

Obstacles necessary to be overcome to achieve your objective	**Individually necessary solutions to overcome the obstacle**
•	• •
•	• •
•	• •
•	• •

In case you reduced the obstacles through expertise, remember that you could use an evaluation matrix while keeping in mind what criteria are particularly important to you. Feel free to use the matrix below to rank your solutions:

IDEAS	***Solution 1***	***Solution 2***	***Solution 3***	***Solution 4***
CRITERIA				
Is it innovative?	0	0	0	0
Is it effective?	0	0	0	0
Is it realisable?	0	0	0	0
Is it cost-efficient?	0	0	0	0
Is it unharmful?	0	0	0	0
Is it politically attractive?	0	0	0	0
Is it timely implementable?	0	0	0	0
Is it adaptable?	0	0	0	0
	0	0	0	0
	0	0	0	0
TOTAL	0	0	0	0

PART 3 - FIRST PRINCIPLES THINKING IN COMPARISON TO OTHER METHODS

After having addressed the step-by-step process of first principles thinking in depth, it is time to see how it compares to other problem-solving methods. Though this list is by no means exhaustive, it does include some of the most prominent problem-solving methods and techniques. For example, we begin with an overview of analogical thinking to exemplify a method that contrasts greatly from first principles thinking, whereas the other methods mentioned—namely analytical, design, lateral and computational thinking—share more traits in common with first principles thinking but nevertheless also differ from one another in their unique ways. Finally, this part of the manual demonstrates the role that first principles play in abductive, deductive, and inductive reasoning as well as the modern scientific method in general. For demonstrative purposes, we will continue to apply the case of Cape Town in our examples.

3.1. Analogical thinking

Analogical thinkers embrace a comparative approach to tackling societal challenges. An analogy is a comparison between objects that highlights aspects in which they are thought to be similar. In turn, analogical problem-solvers first search for similar cases that have successfully tackled a societal challenge or never experienced it in the first place, and then examine what has worked well and not so well in these instances. Subsequently, this person would apply the identified good practices to their situation with minor modifications in accordance with the needs of their own unique situation.[43] Many societal problem-solvers, such as policymakers, NGOs and donor agencies, traditionally employ analogical thinking to generate insights and formulate possible solutions to their problems at hand—with considerable success.

Thus, to tackle the challenge of water scarcity in Cape Town, analogical thinkers would first identify São Paulo, Las Vegas, Beijing, New Delhi and Cairo as being cities that have faced and/or overcome water scarcity.[44] Through the examination of these cases they would identify potential solutions such as improving the efficiency of irrigation water and water recycling mechanisms,[45] tapping more groundwater instead of focusing on above-ground reservoirs,[46] improving the health of forests,[47] increasing awareness and education on water scarcity,[48] and capping population sizes.[49] Depending on the particulars surrounding water scarcity in Cape

Town as well as available resources, analogical problem-solvers would pick and adapt the most suitable and promising solutions.

	Analogical thinking	**First principles thinking**
Assumptions	Accepts assumptions.	Challenges assumptions.
Solution source	Uses analogies to come up with solutions.	Uses first principles to come up with solutions.
Solution type	Existing solutions (with minor alterations).	Profoundly new solutions.
Method	Looks at what solutions have been effective in similar contexts and duplicates them with minor alterations to own challenge at hand.	Asks critical questions to boil down a challenge to its core, identifies fundamental truths, asks "how-questions" about these first principles to come up with new ideas and asks critical questions to refine ideas.
Suitability	Works well when effective solutions in similar contexts are available and duplicable.	Works well when current solutions are ineffective, overly costly/inefficient or non-existent.

3.2. Analytical thinking

Analytic thinkers embrace a systematic approach to tackling societal challenges. They first collect and cluster relevant information regarding a societal challenge, after which they distil it to what is necessary to understand the challenge from different angles. The remaining information is then systematically analysed and interpreted to identify patterns and posit possible causes. These causes are then typically verified using tests. Lastly, being aware of all aspects and available options, they develop solutions to prevent the challenge from occurring partially or entirely.[50]

Thus, to tackle the challenge of water scarcity in Cape Town, analytic thinkers would first learn everything there is to know about the challenge, among which, regarding streams, consumption, rainfall, quality, catchments, evaporation, etc. This information is then analysed to identify causes such as there being insufficient rainfall, there being too many inhabitants, water reserves being insufficient and residents over-consuming water. These causes may then be verified, for example by correlating the degree of water scarcity against the number of inhabitants, per capita water consumption and quantity of rainfall. Lastly, based on the evidence and knowledge gained regarding patterns, cause-effect and possible solutions, decisions are made as to what (combination of) actions are most likely to be effective in reducing water scarcity.

	Analytical thinking	First principles thinking
Assumptions	Tests assumptions.	Challenges assumptions.
Solution source	Uses causes to come up with solutions.	Uses first principles to come up with solutions.
Solution type	Existing solutions (with minor alterations) or new-ish solutions.	Profoundly new solutions.
Approach	Systematic.	Scientific.
Method	Considers, clusters, tests and analyses all relevant information and evidence regarding the patterns, cause-effect and available options of a challenge at hand, after which the most logical (combination of) actions are selected.	Asks critical questions to boil down a challenge to its core, identifies fundamental truths, asks "how-questions" about these first principles to come up with new ideas and asks critical questions to refine ideas.
Suitability	Works well when societal challenges are complex and multifaceted.	Works well when societal challenges are either complex or simple, as long as they can be made concrete and be demarcated to a certain territory.

3.3. Design thinking

Design thinkers embrace a human-centred approach to tackling societal challenges. They first observe, engage and empathise with stakeholders in order to understand their experiences, motivations and needs without allowing themselves to be influenced by their personal assumptions. They then analyse and synthesise their findings to develop a problem statement that revolves around a certain human need. Based on their thorough knowledge of the stakeholders and through techniques such as brainstorming, they examine alternative ways of viewing the problem and generate as many possible solutions as possible. The most promising solutions are then turned into prototypes and tested by themselves or the stakeholders. User feedback is then used to accept, improve or reject each solution. The resulting solution is then, again, rigorously tested and possibly adapted.[51]

Thus, to tackle the challenge of water scarcity in Cape Town, design thinkers would examine the human factor behind, for example, overconsumption by identifying in what conditions Capetonians overconsume, and how they think, behave and feel about water as a commodity—while maintaining an open mind. A resulting problem statement could be something like "Capetonians value water not only as a means to stay alive but also to maintain dignity". In brainstorm sessions they would explore questions such as "How might we discourage water overconsumption without compromising on dignity?" Answers to this question in the form of solutions, such as "decreasing the amount of dust (that makes people

feel less clean and thereby crave a shower) in the streets", are then tested, refined and finally accepted or rejected.

	Design thinking	**First principles thinking**
Assumptions	Sets aside assumptions.	Challenges assumptions.
Solution source	Uses human empathy to come up with solutions.	Uses first principles to come up with solutions.
Solution type	Profoundly new solutions.	Profoundly new solutions.
Approach	Human-centred.	Scientific.
Method	Observes, engages and empathises with stakeholders to truly understand their experiences, motivations and needs; thinks of a wide variety of solutions; and tests and refines the solutions.	Asks critical questions to boil down a challenge to its core, identifies fundamental truths, asks "how-questions" about these first principles to come up with new ideas and asks critical questions to refine ideas.
Suitability	Works well with (undefined) challenges in which humans play a central role.	Works well with (defined) challenges in which humans may or may not play a central role.

3.4. Lateral thinking

Lateral thinkers, also known as horizontal, non-linear, non-sequential or non-vertical thinkers, embrace a non-linear approach to tackling societal challenges. They aim to generate new ideas by forging asymmetric patterns not through following a predefined set of steps but rather by engaging in different (horizontal) activities that stimulate creative thinking. Such activities include thinking of alternative uses for a concept, object or product; thinking of solutions that will not tackle the challenge;[52] describing the ideal solution and then thinking backwards to find its starting point; visualising the challenge;[53] exposing yourself to new information and experiences that serve as ingredients for pattern creation and future epiphanies; listing words or objects somewhat relevant to the challenge and thinking of ways to use them as a solution; thinking about your challenge in a different location; taking a break from your challenge to allow your mind to wander freely and let the subconscious do its work.[54]

Thus, to tackle the challenge of water scarcity in Cape Town, lateral thinkers would engage in activities such as thinking of water as a means to control temperature; entertaining the thought of granting unrestricted access to water or funnelling fresh water to the ocean; visualising Capetonians having access to an abundance of water and thinking where this water could have come from; reading scientific studies as well as social media discussions about water shortage; thinking how a water gun can be used to combat water shortage; physically or

mentally going to a place where there is an abundance of fresh water such as the Arctic glaciers; and/or engaging in other activities such as gardening.

	Lateral thinking	**First principles thinking**
Assumptions	Disregards (and thereby challenges) assumptions.	Challenges assumptions.
Solution source	Uses asymmetric patterns to come up with solutions.	Uses first principles to come up with solutions.
Solution type	Profoundly new solutions.	Profoundly new solutions.
Approach	Non-linear.	Scientific.
Method	Forges asymmetric patterns by engaging in different activities that stimulate creative thinking, such as thinking of alternative uses, ineffective solutions, ideal solutions, semi-random objects as a solution. Changing location, visualising, digesting new information and taking breaks enhance this process.	Follows a step-by-step process of asking critical questions to boil down a challenge to its core, identifying fundamental truths, asking "how-questions" about these first principles to come up with new ideas and asking critical questions to refine ideas.
Suitability	Works well when current solutions are ineffective, overly costly/inefficient or non-existent.	Works well when current solutions are ineffective, overly costly/inefficient or non-existent.

3.5. Computational thinking

Computational thinkers embrace an algorithmic approach to tackle societal challenges. They first break down a challenge into a set of (relational and procedural) rules and instructions that a computer could generate.[55] The computer can then shed light on patterns and irregularities in the data, after which computational thinkers analyse and interpret them with the goal to find the general principles that generate these patterns. Finally, they can devise step-by-step instructions (algorithms) to solve similar problems quickly.

Thus, to tackle the challenge of water scarcity in Cape Town, computational thinkers would break down the challenge to variables relating to water sources, usage, waste or evaporation, streams, leaks, etc. to identify patterns in the data. They may find, for example, that the quality of water decreases during transport from water reserves to households as it gets warmer. This information (or causal principle) does not only tell computational thinkers where a problem is located and how it works, but it also highlights possible avenues for solutions. From this they can, for example, design an algorithm that computes how much temperature decrease is necessary to maintain a safe level of water quality.

	Computational thinking	First principles thinking
Assumptions	Uses scientifically-backed assumptions as rules.	Challenges assumptions.
Solution source	Uses computable data and patterns to come up with solutions.	Uses first principles to come up with solutions.
Solution type	Computational solutions.	Profoundly new solutions.
Approach	Scientific (algorithmic).	Scientific (foundationalist).
Method	Breaks down a challenge into a set of computable rules, identifies patterns, extracts general principles and designs algorithms to solve problems.	Asks critical questions to boil down a challenge to its core, identifies fundamental truths, asks "how-questions" about these first principles to come up with new ideas and asks critical questions to refine ideas.
Suitability	Works well when there are vast amounts of data available regarding a societal challenge.	Works well when there is not so much data or effective solutions available regarding a societal challenge.

3.6. First principles in abductive, deductive and inductive reasoning

In the late 19th century, the American logician Charles Sanders Peirce introduced the concept of *abductive reasoning*, a form of logic that would prove complementary to the already existing methods of *abductive* and *inductive reasoning*. Traceable back to the works of Aristotle, deduction is a top-down form of logic whereby a specific conclusion is inferred from a general rule and a set of observations. On the other hand, induction refers to a bottom-up form of logic by which a general rule is reached by extrapolating from specific observations. Although the latter two approaches to problem-solving had served philosophers for centuries, Peirce's application of all three forms resulted to be a great innovation in the development of the modern scientific method.[56]

Peirce's three-step example		
I. Abduction	***II. Deduction***	***III. Induction***
Rule: All the beans in this bag are white. *Result*: These beans are white. *Case*: These beans are from this bag.	*Rule*: All the beans in this bag are white. *Case*: These beans are from this bag. *Result*: These beans are white.	*Case*: These beans are from this bag. *Result*: These beans are white. *Rule*: All the beans in this bag are white.

Peirce's abductive approach was based on inferring what he called a "case" from a "result" and a "rule". While it proved to be the least logically secure of the three approaches in terms of finding a unique explanation for an observation, it did provide the possibility of making an inference to the best possible explanation given the limited information available to the problem-solver. Therefore, abduction is very useful for the creation of hypotheses, which can then be tested through the more logically secure method of deduction, by which a valid "result" can be inferred from the "case" (hypothesis) and the initial "rule". Finally, induction can be used to generalise the results of the previous steps by extrapolating a general "rule" from a specific "result" and "case". In this way, the process of abduction-deduction-induction outlines the basic steps of the scientific method: creating a hypothesis, testing the hypothesis, and generalising the results of the research to build a theory.

Cape Town example	**Your turn**
I. Abduction	***I. Abduction***
First Principle: Overconsumption of water leads to water shortage.	*First Principle*:
Result: There is a water shortage in Cape Town.	*Result*:
Hypothesis: Therefore, residents of Cape Town are overconsuming water.	*Hypothesis*:

What Peirce refers to as "rules" are in fact first principles. Returning to our example of Cape Town, we can create a hypothesis (residents of Cape Town are overconsuming water) based on one of our first principles (overconsumption of water leads to water shortage) and a result or observation (there is a water shortage in Cape Town). As we continue through the steps, follow along with corresponding examples from your own societal challenge.

Cape Town example	**Your turn**
II. Deduction	***II. Deduction***
First Principle: Overconsumption of water leads to water shortage.	*First Principle*:
Hypothesis: Residents of Cape Town are overconsuming water.	*Hypothesis*:
Result: There is a water shortage in Cape Town.	*Result*:

Secondly, we can proceed to test our hypothesis by seeing if the result can, in turn, be logically inferred from the first principle and that hypothesis.

Cape Town example	Your turn
III. Induction	***III. Induction***
Hypothesis: Therefore, residents of Cape Town might be overconsuming water.	*Hypothesis*:
Result: There is a water shortage in Cape Town.	*Result*:
First Principle: Overconsumption of water leads to water shortage.	*First Principle*:

Finally, we try to generalise our first principle by extrapolating a universally applicable theory from our tested hypothesis and the original result or observation. However, even though upon completion the process may appear to be logically sound, it is important to keep in mind that while the first principle may be a valid explanation for the hypothesis, it is not necessarily the *only* explanation. Therefore, this process should be repeated until all applicable first principles have been exhausted. Even more importantly, it should be kept in mind that if our first principle is actually incorrect, this will affect the validity of any conclusions reached from it. Such is the weight of first principles.

PART 4 - FINAL REMARKS

As we near the end of this manual and, thus, our journey to better understand and master the potential of first principles thinking, we would like to reiterate some of the most important points that have been covered so far. What follows is a summary of the main lessons and takeaways of the manual's contents, followed by a brief discussion of some possible limitations to first principles thinking that you may encounter as you gain more experience applying the method to various societal challenges in the future.

4.1. Main lessons

As we learned, first principles thinking is deeply rooted in science, so to be an effective first principles thinker you have to begin thinking like a scientist: question your original assumptions, have an open mind about possible solutions and never accept any obstacle as insurmountable. However, as you go through the process of deconstructing your challenges and then reconstructing them from the bottom up, do not forget that creativity is just as important as logic and knowledge are. Try to visualise your ideas to help activate the creative engine, and be careful not to get caught up on any single step or question for too long, as such prolonged dwelling can lead to frustration and actually hinder your progress. If at any point you feel a lack of inspiration or become overwhelmed by the scope of your task, ask Socratic questions to put your train of thought back on track. Keep in mind that there is no set time to complete the steps of the process. In fact, we encourage you to approach the steps that have been laid out in this manual at your own discretion, as only you can decide whether the challenge you face requires a more meticulous or liberal approach to our methodology.

Moreover, now that you have learned not only the process of first principles thinking but also become acquainted with a number of alternative problem-solving methods, do not be afraid to mix and match elements from various methods according to your current needs. First principles thinking is not about being a purist but about being an innovative and effective problem-solver. For this reason, you might also find it productive to work with other thinkers from different backgrounds, as different specialisations and areas of expertise can often complement one another in the creative process.

4.2. Limitations (and how to deal with them)

First principles thinking has certain limitations and downsides that are good to be aware of. Nevertheless, being first principles thinkers ourselves, we also identified ways to deal with them:

1. **It may need some time to identify solutions**. If you follow the first principles thinking steps outlined in this manual meticulously, you might find yourself spending a few hours before getting to truly innovative and actionable solutions. Of course, this also depends on the size and number of obstacles you seek to tackle, how many Socratic questions you wish to pursue as well as your preferred level of abstraction and the accessibility of information regarding first principles. In other words, it is largely up to you how long it takes. In case you start applying this method more regularly in different aspects of your personal and professional life, you are likely to find yourself going through the steps on automatic pilot; by this time it becomes easier and therefore quicker to repress your assumptions, identify your obstacles, ask the right questions, identify first principles and so on. At some point you might even find yourself skipping some steps entirely because questions and solutions start appearing right away.

2. **It does not always result in discovering solutions that you wish for**. While the method typically generates ideas that are unconventional and innovative, they are not always the panaceas you hoped to discover. This can be frustrating but is simply part of the problem-solving process. In case you are unsatisfied with the solutions you generated, you might want to select other obstacles, or ask a friend or colleague to give it a shot. Although steps VI and VII encourage you to refine your ideas in a way that makes them more applicable to the reality of your challenge, the ideas are still likely to be unconventional, which means you should anticipate some resistance and scepticism.

3. **It does not always generate durable solutions**. With most innovations that are upscalable or duplicable through analogical thinking, there is a risk that they become excessively used and thereby create unintended consequences. The widespread availability and use of modern fishing techniques, for example, has resulted in overfishing and thereby the depletion (and sometimes even extinction) of certain fish stocks. In other words, a new societal challenge has been created. Unless you find a durable solution right away, you should be prepared to continue to switch between being a first principles thinker (to come up with solutions) and an analogical thinker (to spread solutions).

4. **It is less applicable to wicked problems**. If you seek to tackle very complex and multifaceted challenges through the use of first principles thinking, you may get lost in the process because it would require you to select multiple obstacles that each require multiple and/or very effective solutions to be overcome. This, in turn, requires you to pursue multiple lines of questioning and identify multiple first principles at different

levels of abstraction. If you wish to make a meaningful contribution without getting lost, tired or frustrated, we advise you to cut wicked problems into more manageable sub-challenges, like analytical thinkers would do. Instead of seeking to reverse global warming as such, you may want to focus on tempering one single factor that contributes to global warming, such as carbon emissions, and start within a city where emissions are high. Indeed, this challenge is still intimidating but already much more manageable. The more concrete the challenge and the more demarcated the territory, the more elemental and tailored information (first principles) you will find, which in turn increases the likelihood to discover solutions that are suited to the task at hand.

5. **It may actually confine your thinking**. Although the method encourages you to question assumptions and be open to unconventional ideas, it might at the same time discourage you from exploiting alternative problem-solving techniques that offer additional valuable insights. Analytical thinking might, for example, help you approach the challenge from different angles, identify root causes and organise information. Design thinking, on the other hand, may encourage you to consider the human factor when coming up with new solutions. Furthermore, analogical thinking might help you identify existing solutions that you can, in turn, improve through the use of first principles thinking. In other words, first principles are not the only source of meaningful solutions.

6. **It is designed to generate solutions, not implement them.** Indeed, the process of first principles thinking ends once ideas have been generated and refined. However, ideas themselves are not enough to tackle societal challenges; they must be implemented to become viable solutions that can really make a difference. In case you have the resources, knowledge and authority to implement the solutions yourself, go ahead and do so. As with any new idea, there is risk and uncertainty involved because the precise workings, costs and effects are not always fully gaugeable. As such, if time and resources allow it, it might be fruitful to start with a pilot in a controlled environment. This allows you to monitor, evaluate and refine the workings of the solution. However, if you find that you lack the means to implement your solutions yourself, do not hesitate to contact FIPS to help realise your goals. After all, it is part of our mission to get in touch with organisations that might possess the necessary resources, reach out to specialists who might have the required skills or even propose your ideas to government bodies whose authority could be a vehicle for implementation.

4.3. Send us your feedback

We hope that this manual has and will continue to be of good use to you, and we look forward to hearing about your experiences with first principles thinking. If you would like to share some of the innovative ideas you have come up with, ask any still unanswered questions or have us address any concerns or suggestions that could lead to the improvement of this manual in the future, do not hesitate to contact: info@innovativepolicysolutions.org.

For further examples of first principles thinking at work, please visit the FIPS website www.innovativepolicysolutions.org, where you will find our solution report to increase literacy rates among women in rural Mauritania along with other articles in a growing library of publications.[57] If you would like to be a contributor to one of our solutions reports or publish an article of your own, we invite you to get in touch.

KEY TERMS

Term	Definition	Page
Abductive reasoning	A form of logic whereby the best possible explanation is inferred from the limited amount of information available.	40
Analogical thinking	A societal problem-solving method that duplicates solutions applied to similar contexts.	35
Analytical thinking	A societal problem-solving method that distils and analyses a wide variety of information to understand the causes of the challenge from different angles and propose solutions.	36
Cartesian doubt	The act of expressing scepticism about the validity of one's beliefs and assumptions.	12
Computational thinking	A societal problem-solving method that breaks down a challenge into a set of computable rules to learn about its workings and design algorithms to come up with solutions.	39
Deductive reasoning	A top-down form of logic whereby a specific conclusion is inferred from a general rule and a set of observations.	40
Design thinking	A societal problem-solving method that focuses on the experiences, motivations and needs of stakeholders to come up with solutions.	37
False principle	A scientifically unproven belief or assumption used as a norm to evaluate objects, behaviour and outcomes.	16
First principles thinking	A societal problem-solving method that rigorously questions assumptions to get to the truthful core of a challenge and from there come up with new solutions.	1
First principle	The first basis from which a thing is known.	15
Greedy reductionism	The act of underestimating complexities and skipping important steps in a rush to arrive at first principles as soon as possible.	16
Inductive reasoning	A bottom-up form of logic whereby a general rule is reached by extrapolating from specific observations.	40
Lateral thinking	A societal problem-solving method that engages in different activities that stimulate creative thinking to forge asymmetric patterns and come up with solutions.	38
Societal challenge	Any issue that affects the collective welfare of a community.	3
Socratic questioning	A truth-finding method that questions the validity of one's beliefs and assumptions in a disciplined, rigorous and thoughtful manner.	12

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First Principles Thinking

Step 1 Identify your objective

Step 2 List your obstacles

Step 3 Question your assumptions

Step 4 Uncover your first principles

Step 5 Come up with new ideas

Step 6 Refine your ideas

Step 7 Select your solutions

About this manual

The manual you have in front of you was created in response to the great number of challenges that currently affect our global society. At the Factory for Innovative Policy Solutions, we believe that those challenges—whether economic or environmental, urban or rural, European or African—persist largely due to the ineffectiveness of the problem-solving methods that have traditionally been used to tackle them. This manual thus aims to introduce you to the fundamentals of first principles thinking and equip you with the problem-solving tools you need to begin generating truly innovative ideas!