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Preparing the Next Generation of Engineers for Decision Making under Deep Uncertainty: Exploring the Pedagogical Role of the Decisions for the Decade Game

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Abstract

This analysis aimed to explore the role of a serious game called Decisions for the Decade (D4tD) in teaching students about climate change adaptation and decision making under deep uncertainty within the context of this university's civil and environmental engineering courses. The game, developed by the Red Cross/Red Crescent Climate Center and the World Bank, was designed to support learning and conversations about long-term investments under uncertainty by making participants more familiar with the process of planning for extremes and climate change impacts while minimizing risk. This work included three cohorts of students: two graduate level courses and one undergraduate level course. The students' self-reported quantitative and qualitative results were analyzed to determine the impact of the D4tD game in improving student understanding of and attitudes towards uncertainty and robust decision making for climate change adaptation and planning. Quantitative results implied that students found it difficult to make beneficial decisions as uncertainty increased. Students seemed to be more cautious when making collective decisions compared to individual decisions. This collective risk aversion highlighted the benefits of collective learning and decision making for risk management. From the qualitative results, common themes (such as "Informed Decision Making" and "Risk Preparedness"), common keywords ("flood", "drought", "climate", "uncertainty"), and varying emotions observed in student responses indicated students' awareness of and growing understanding about uncertainty and robust decision making, and pointed to the social/psychological aspects of playing the D4tD game and making decisions under uncertainty. In conclusion, these results attest to the benefit of the D4tD game as a tool within this university and departmental context to improve student understanding of and attitudes towards uncertainty and robust decision making for climate change adaptation and risk management.

The first author of this paper is a PhD student, an EED member, and would like to self-nominate this paper for the best student paper award. Thank you for your consideration.

Key words:

climate change adaptation, robust decision making, game-based learning, innovative pedagogy, uncertainty, risk

1.0 Introduction

1.1 Decision Making under Deep Uncertainty (DMDU)

Problems can be defined as deeply uncertain when impact analysts cannot agree on the conceptual models that could be used to represent probable futures, the probability distributions representing uncertainty of parameters in the future, and/or how to value the different outcomes [1]. Decisions under climate change are deeply uncertain, and DMDU approaches have frequently been applied for long term planning for urban infrastructure [2]–[4]. Decision makers must plan and take some form of adaptive action (including no action or deferred action) to address the impacts of climate change. These actions tend to be informed by complex modeling analyses, and it is often difficult to communicate the modeling results as well as the advantages and disadvantages of different actions to stakeholders and decision makers. It is equally if not more difficult to communicate these concepts to civil and environmental engineering students who will be confronted with similar decisions in their future careers. Serious games may offer some solutions to these challenges.

1.2 Serious games for decision making under climate change

Serious games can be defined as games or role play used for educational purposes, including in-person, virtual, and online role play [5]–[7]. In many serious games, players work collaboratively to solve a fabricated but realistic problem [7], [8]. Serious games share a number of common characteristics, including the ability to capture complexity, to highlight the importance of effective communication, and to provide space for reflexive learning, collaboration, and dialogue [5]. Because of the complex and collaborative nature of decisions that must be made regarding climate change, serious games are often used as tools for climate change adaptation and planning.

Research surrounding serious games has demonstrated several benefits as well as potential limitations. Serious games are an effective tool for engaging with diverse individuals and enabling social learning [5], [7], [9], and can encourage collective action in public policy-making contexts [8]. These games can therefore be useful for improving communication and decision making capacity, particularly about climate change and risk management amongst diverse stakeholders [6], [9]. In the classroom setting, serious games fall within the category of active learning, fostering a more student centered approach that benefits students' well-being across multiple aspects of life [10], [11].

While serious game elements can capture randomness, probability, uncertainty, and decision making under multiple criteria [6], [7], [12], game developers must ensure that games are not too long or complex. Without a balance of qualitative and quantitative components, serious games can be tedious and/or ineffective [5], [9]. In addition, it is difficult to assess the

effectiveness of serious games without explicitly considering learning outcomes and behavior change [5], [7], which can be difficult to measure for assessment.

In summary, classrooms offer particularly useful arenas for serious games. The authors' goal was to explore the role of a serious game called Decisions for the Decade (D4tD) in teaching students about climate change adaptation and decision making under deep uncertainty, within the context of this university's civil and environmental engineering courses. The following section describes the game and methodology in more detail.

2.0 Methodology

Decisions for the Decade (D4tD) is a serious game designed to support learning and conversations about long-term investments under uncertainty [13]. The goal of the game is to make participants more familiar with the process of planning for extremes and for climate change impacts, as well as risk minimization [13]. The game was therefore aligned with the course learning objectives to improve student understanding of uncertainty and robust decision making. The game implementation summarized in Section 2.1 is very similar to the detailed instructions found at [13], and instructors made use of resources that are available in the Appendix and upon request from the authors.

2.1 In-Class Implementation of Decisions for the Decade (D4tD)

This serious game was played with three cohorts of students: S22 and S23 (graduate level course about climate change adaptation) and F22 (undergraduate level course introducing students to Civil and Environmental Engineering). Each cohort played the game within an 80-minute class, spending approximately 10-15 minutes listening to instructors explain the game using a PowerPoint presentation (see Appendix), 40-55 minutes playing the game, and 10 minutes debriefing after the game. In order to assess student understanding, the authors conducted quantitative analysis based on students' de-identified self-reported results from the game for all three cohorts, and qualitative analysis based on students' de-identified responses to a reflection question at the graduate level. Students were informed that grading was solely based on completion of their quantitative and/or qualitative responses with good faith effort.

Each student participant in the game represented an imaginary province, and students also formed groups of four students each, where each group represented an imaginary nation. Each imaginary nation and province was allocated ten points at the beginning of each of the four decades. For each decade, students had to make individual provincial decisions as well as collective national decisions to determine how to allocate ten points to protect their province and nation from climate change risks. Points could be allocated towards flood protection, drought protection, or economic development. At the end of each decade, all the points allocated towards

economic development were recorded as prosperity points. For each flood or drought that occurred during the decade, points that had been allocated for flood or drought protection respectively could be 'used'. However, if a flood or drought occurred after all allocated flood or drought protection points had been 'used', a nation or province would experience a humanitarian crisis, and lose all the points allocated for economic development for that decade. In the latter decades (Decades 3 and 4), students were offered a 'Robust Option', represented by a card which they could 'purchase' for eight points. Imaginary nations and provinces with this 'Robust Option' were not susceptible to humanitarian crises, but only retained two prosperity points at the end of the decade. For each decade, students recorded their point allocations, the number of prosperity points, and the number of crises for their imaginary province and nation on their game board (Figure 1).

Figure 1: example of a game board used by provinces and nations to record point allocations, number of prosperity points, and number of crises

For this game, the climate during each decade was simulated by focusing on extreme precipitation patterns, which were described categorically as normal, drought, or flood conditions. The instructor used different methods to simulate precipitation. For all three cohorts, a six-sided die was rolled ten times to represent the first decade, where rolling a 1 simulated a drought, a 6 simulated a flood, and all other rolls simulated a normal year. As the game progressed, the method used to estimate precipitation became more complex, including rolling an 8-sided die (flood simulated by rolling a 6, 7, or 8) and flipping a cone, where the probability of drought (cone landing large side up), flood (cone landing large side down), or normal precipitation (cone landing on its side) were virtually unknown. The method used to simulate precipitation and the possibility of receiving a 'Robust Option' were communicated to the students before they allocated their points for the respective decade, and methods used to simulate precipitation for each decade for each cohort are reported in Table 1.

Table 1: method used to simulate precipitation in each decade for each cohort, as well as number of robust options offered to each cohort

	Decade 1	Decade 2	Decade 3	Decade 4	Robust options offered
S22	6-sided die	8-sided die	8-sided die	cone	Decades 3 and 4 (16 total)
F22	6-sided die	8-sided die	8-sided die	cone	Decades 3 and 4 (8 total)
S23	6-sided die	8-sided die	cone	8-sided die	Decades 3 and 4 (8 total)

2.2 Quantitative Analysis

For all three cohorts (S22, F23, and S23), at the end of the game, students turned in their provincial and national game boards (Figure 1) with recorded points and crises, and this assignment was graded for completion. For provincial boards representing individual decisions, a total of 23 game boards were received and analyzed for S22, 32 for F23, and 30 for S23. For national boards representing collective decisions, a total of 6 game boards were received and analyzed for S22, 9 for F23, and 8 for S23. The point allocations and crises from each game board for each cohort were summarized in Excel.

2.3 Qualitative Analysis

At the end of the game, the two graduate level cohorts (S22 and S23) were asked to reflect upon their learning and feelings. The following question was asked to collect responses: "*In a paragraph, provide your emotions and understanding of uncertainty and robust decision making as a result of playing this game*." This assignment was also graded for completion. The submissions were collected through the student learning management system and the responses were downloaded and de-identified before analysis. A total of 23 responses were received for S22, and 27 for S23.

The examination of participant responses involved the employment of thematic analysis following the framework proposed by Braun and Clarke [14]. The responses were subjected to individual scrutiny by two distinct coders and subsequently categorized into themes delineated by each coder. The coders initiated the analysis independently, employing an inductive methodology that commenced with specific content analysis, gradually transitioning into broader abstractions, and ultimately culminating in the identification of overarching themes [15]. Throughout the analytical process, the initial subthemes were subject to refinements, while new themes emerged to comprehensively encapsulate the diverse array of comments. Subsequently, both coders reached a consensus on the final subthemes and themes through collaborative deliberation. A continual reevaluation of the data was carried out during analysis to accommodate the emergence of new codes and themes [16]. In conjunction with the identified thematic components, an analysis of the responses included the computation of average word

counts. The frequency of pivotal terms, as determined through consensus among the authors, was quantified and examined using Python.

3.0 Results

3.1 Results from Quantitative Analysis

The percentage of years that were simulated as flood years, drought years, and normal years for each decade for each cohort was similar, but not identical, and impossible to predict, suggesting that this aspect of the serious game was mimicking 'real world' uncertainty (Figure 2). Each cohort experienced at least 40% normal years when averaged across all four decades, but cohorts' experience of drought ranged from 0-40% and experience of flood ranged from 0-40%.

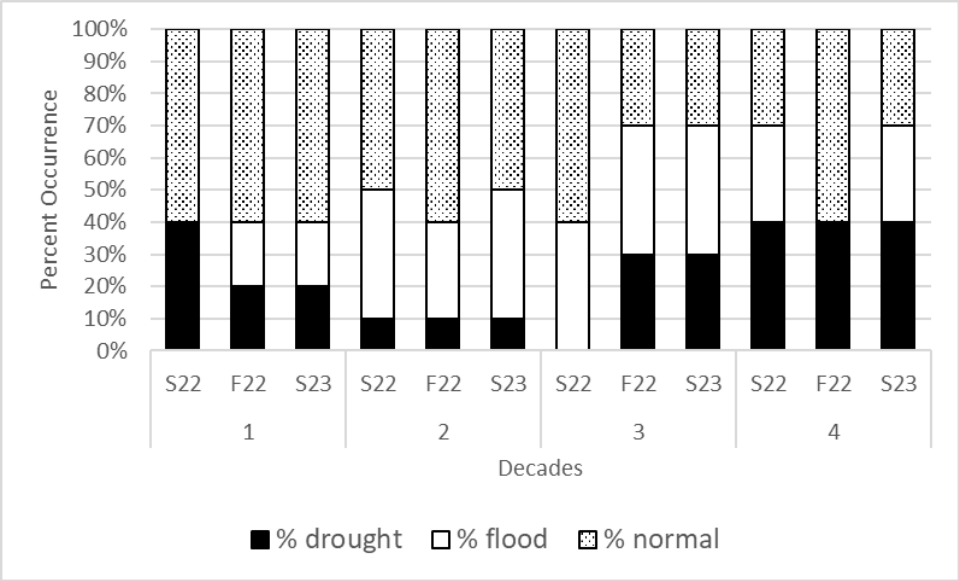

Figure 2: percentage of drought, flood years, and normal years simulated for each cohort for each decade

The quantitative analysis was conducted separately for provinces (i.e. individual students) and nations (i.e. groups of students), as discussed in Sections 3.1.1 and 3.1.2 below.

3.1.1 Provincial Results

The quantitative results at the provincial level summarized the average number of prosperity points for each province over time for each cohort and decade (Figure 3), and the number of provinces with at least one crisis for each cohort and decade (Figure 4).

The average number of prosperity points increased from Decade 1 through 3 for provinces in S22, with a decrease in Decade 4, where the cone method was used to simulate precipitation (Figure 3). The number of provinces with at least one crisis in Figure 4 shows a similar trend: in Decade 1, many provinces experienced at least one crisis. As the decades progressed, fewer provinces reported crises, with an increase in Decade 4. In the last decade, almost half the students (43%) selected the 'Robust Option' (see Table 2).

The F22 provinces were initially successful in allocating points: the average number of prosperity points was the highest in Decade 1 and no provinces reported a crisis in Decade 1 (Figures 2 and 4). However, provinces seemed to become more cautious as the decades progressed and uncertainty increased: the average number of prosperity points in Figure 3 decreased over time. The number of provinces with at least one crisis remained relatively low, except for Decade 3, when the 8-sided die was introduced (Figure 4). Because of the limited number of robust options offered to the class, very few students (12.5%) could select the robust option in Decade 4 (see Table 2).

Similar patterns were observed for S23.The number of provinces with at least one crisis increased in Decade 2, when the 8-sided die was introduced. The largest number of provinces with at least one crisis was observed in Decade 3, where precipitation was simulated using the cone method (Figures 3 and 4). Compared to F22, more provinces in S23 reported at least one crisis, as shown in Figure 4. Because of the limited number of robust options offered to the class, very few students (6.7%) could select the robust option in Decade 4 (see Table 2).

In summary, the average number of prosperity points reported by provinces tended to be lower in the decades where the method used to simulate precipitation was more uncertain. For S23, this metric was lowest for Decade 3, when the cone method was used. For S22, this metric decreased in Decade 4, when the cone method was used. A similar decrease was not observed when the cone method was used for F22, perhaps because of the higher than average number of normal years observed in Decade 4 when the cone method was used (Figure 2).

Similarly, the number of provinces with at least one crisis tended to increase in the decades where the method used to simulate precipitation was more uncertain. This metric increased in Decade 2 for S23 and for F22, when the 8-sided die was introduced. A similar increase was not observed for S22, perhaps because of the higher than average number of normal years observed in Decade 3 when the 8-sided die was introduced (see Figure 2). However, for S22, an increase in the number of provinces with at least one crisis occurred in Decade 4 when the cone method was introduced.

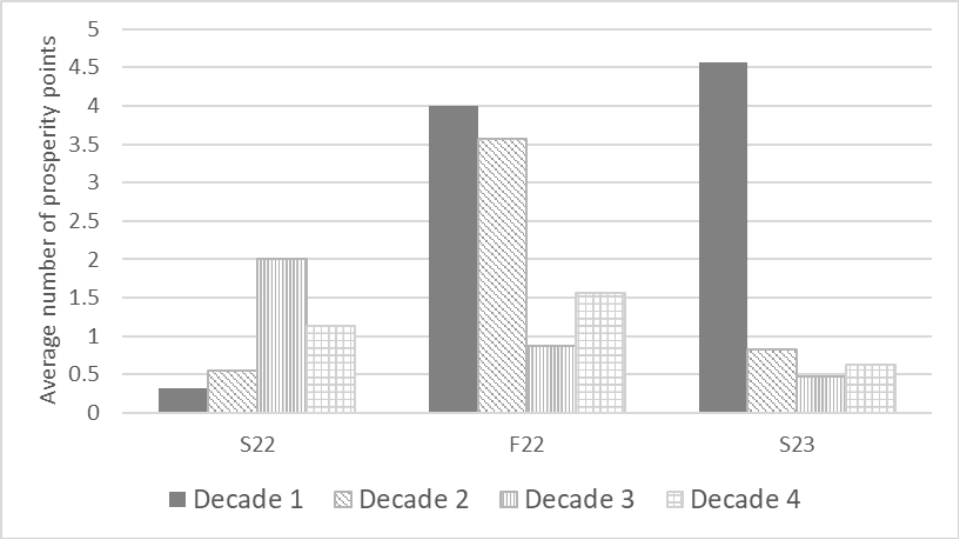

Figure 3: average number of prosperity points reported by each province (i.e. student) for each decade for all cohorts

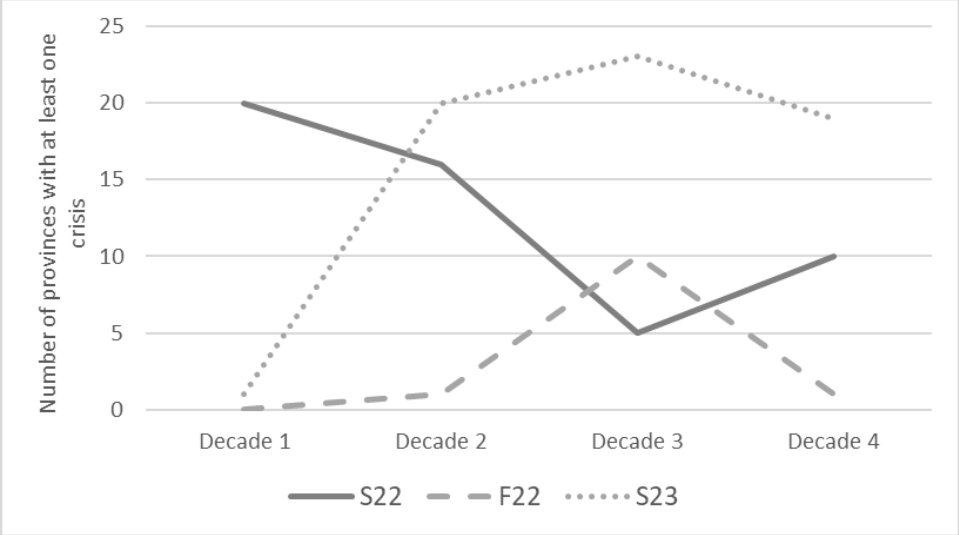

Figure 4: number of provinces with at least one crisis for each decade for all cohorts

3.1.2 National Results

The quantitative results for nations (i.e. groups of students) instead of provinces (i.e. individual students) summarized the average number of prosperity points for each nation for each cohort and decade (Figure 5) and the number of nations with at least one crisis for each cohort and decade (Figure 6).

Similarly to the provinces, the average number of prosperity points for the nations tended to be lower in the decades where the method used to simulate precipitation was more uncertain, and the number of nations with at least one crisis tended to increase in the decades where the

method used to simulate precipitation was more uncertain. For F22 and S23, the average number of prosperity points was lowest in Decades 3 and 4, when the 8-sided die and cone methods were used respectively (Figure 5). The number of nations with at least one crisis increased in Decade 2 for S23 and for F22, when the 8-sided die was introduced. However, similar patterns were not observed for S22: Figure 6 shows that all nations in S22 experienced at least one crisis in Decade 1. As the decades progressed, national prosperity points increased, and the number of crises decreased for S22. For all cohorts in Decade 4, a higher percentage of nations chose the 'Robust Option' than the percentage of provinces for all cohorts (see Table 2), and no crises were observed for any nation in any cohort (see Figure 6).

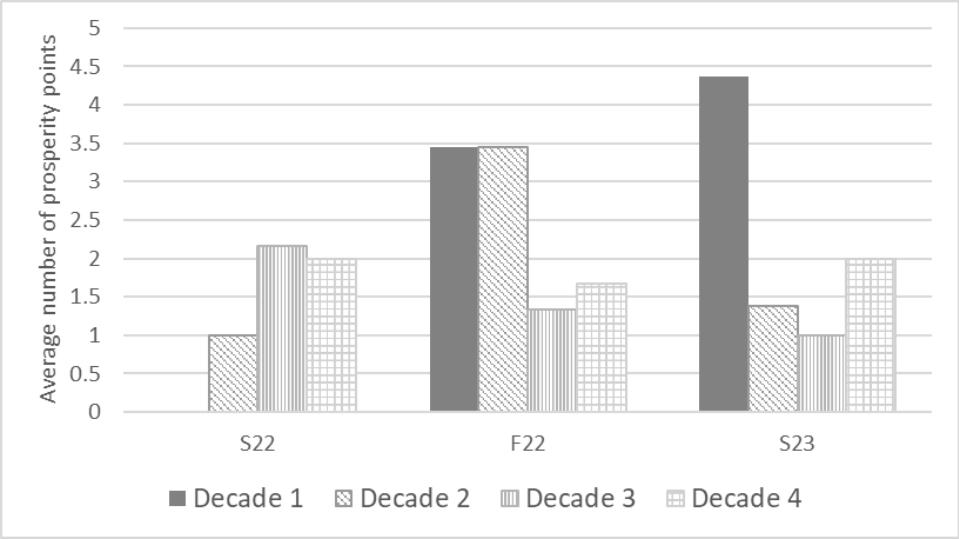

Figure 5: average number of prosperity points reported by each nation for each decade for all cohorts

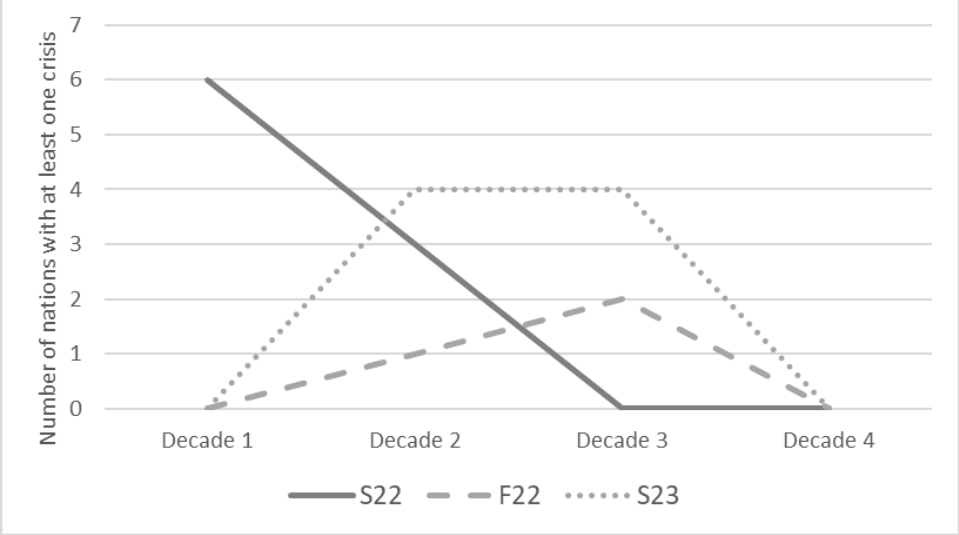

Figure 6: number of nations with at least one crisis for each decade for all cohorts

Table 2: number of robust options offered and selected at the provincial and national levels during Decade 4 for all cohorts

	Total number of robust options offered	Robust options provincial	Robust options national
S22	16	43% (10/23)	100% (6/6)
F22	8	12.5% (4/32)	44% (4/9)
S23	8	6.7% (2/30)	75% (6/8)

3.2 Results from Qualitative Analysis

The qualitative results provided insights into the subthemes and themes identified, the various aspects of the collected responses, including the sample size (N), average word count, recurring themes, and the corresponding frequency of these themes (Tables 3 and 4).

In the context of cohort S22, which consisted of 23 participants, the average word count per student response was 106 words. Several recurring themes have been identified from the responses. The theme of "Informed Decision Making" emerged with a frequency of nine occurrences, highlighting the significance of well-considered choices among the student cohort. Another prominent theme was "Climate Resilience," which appeared ten times, suggesting a collective concern for building the capacity to withstand and adapt to climate-related challenges. Additionally, the theme of "Risk Preparedness" emerged with a frequency of four, indicating an awareness of the importance of being ready to address potential risks and uncertainties.

For cohort S23, composed of 27 participants, the average word count per student response was reported as 161 words, indicating a potentially more detailed and elaborate set of responses compared to cohort S22. The recurring theme of "Informed Decision Making" was reported most often with a frequency of eighteen. The theme of "Risk Preparedness" persisted with a frequency of five, reaffirming the awareness of managing uncertainties. Notably, a new theme emerged in this cohort: "Global Efforts," which appeared four times. This theme pointed to a broader perspective encompassing collaborative initiatives and actions on a global scale.

Table 3: themes and subthemes for student responses to the prompt from S22 and S23 cohorts

Cohort	Themes	Subthemes
S22	Informed decision making	• Strategic planning • Conservative decisions • Research and development • Decision making
	Climate resilience	• Robustness • Climate forecasting • Resilient investment • Climate adaptation • Climate modeling
	Risk preparedness	• Uncertainty management • Risk aversion

S23	Informed decision making	• Decision Making • Informed Choices • Prudent Decision Making • Robust Decision Making • Practical Action • Prudent Choices
	Risk preparedness	• Climate management • Climate risk
	Global efforts	• Collaborative Governance • Collaborative Decision Making • Global Cooperation • Global Disparities

Table 4: the sample size (N), average word count, themes and frequency of the themes emerged from student responses to the prompt from S22 and S23 cohorts

Cohort	N	Average Word Count	Themes	Frequency
S22	23	106	Informed Decision Making	9
			Climate Resilience	10
			Risk Preparedness	4
S23	27	161	Informed Decision Making	18
			Risk Preparedness	5
			Global Efforts	4

Table 5 presents a comparative analysis of the keywords identified by the authors, and frequencies extracted from students' responses to the prompt. These keywords pertain to the specific emphasis instructors intended with this game. Table 5 highlights the differences in keyword frequencies between the two cohorts, shedding light on their relative emphasis on various topics. Notably, "flood" and "drought" were prevalent keywords in both cohorts, which was expected given the focus of this game on water-related challenges. "Climate" and "uncertainty" also appeared with notable frequencies in both sources, indicating their significance in the discussed context. Additionally, the concept of "adaptation" appeared with a relatively lower frequency in both sources, higher in S23 than S22. Interestingly, "probability" was mentioned only in the context of the responses from S23, while "anger" was solely associated with the S22 cohort. The keywords "investment," "protection", and "infrastructure" appeared with varying frequencies in both sources, indicating their relevance to the subject matter. Furthermore, feelings such as "anger", "anxiety", "stress", and "pressure" emerged as secondary keywords, suggesting a potential connection to the broader psychological or social aspects of playing the game.

Table 5: converged list of keywords and their respective frequencies

Converged list of keywords	S22 Frequency	S23 Frequency
infrastructure	4	8
investment	6	19
flood	25	26
drought	20	27
protection	6	13
climate	10	31
adaptation	2	5
uncertainty	21	28
probability	0	5
anger	8	0
pressure	0	1
anxiety	2	3
stress	1	2

4.0 Discussion

A combination of the results from quantitative analyses and trends from qualitative analyses revealed how student understanding about uncertainty and robust decision making was impacted and improved through playing the Decisions for the Decade (D4tD) game. Although S22 was the first time that the instructors played the game in the classroom and methods used to simulate precipitation in S23 were applied in a different order than in S22 and F22 (see Table 1), interesting conclusions can be drawn from all three cohorts about the efficacy of this serious game in this university and departmental context.

The observed decrease in the number of provincial prosperity points and increase in provinces with at least one crisis occurred in the decades where the method used to simulate precipitation was more uncertain (e.g. when the 8-sided die was introduced, or when the cone method was introduced). The cone method had the highest uncertainty of the methods used to simulate precipitation and helped to represent the deep uncertainty associated with climate change. As authors expected, students seemed to find it more difficult to make beneficial decisions (i.e. retain a large number of prosperity points and/or experience few crises) when they were unable to use probability to help allocate points for their province or nation at the beginning of the decade.

In many cases, the results from national decision making were similar to the results from provincial decision making. However, students seemed to generally be more cautious when

making national decisions as compared to provincial decisions. The higher percentage of nations compared to provinces that chose the robust option in Decade 4 and the absence of any crises for any nation for any cohort in Decade 4 highlighted the benefits of collective learning and collective decision making for reducing risks under deep uncertainty.

The common themes and keywords, as well as the average word count observed in qualitative responses, indicated students' awareness of and growing understanding about uncertainty and robust decision making. S22 and S23 shared a couple of common themes ("Informed Decision Making" and "Risk Preparedness") and a few common keywords ("flood", "drought", "climate", "uncertainty"), as shown in Tables 3-5. Many of these themes and keywords were expected, as they were used by the instructors as part of the game description and explanation. However, student responses highlighted their growing understanding about uncertainty beyond simply including these keywords in their responses. As one student from S22 noted, *"[w]e can't know what will happen exactly. So, we have to prepare for the upcoming disasters. If we don't take any useful action, it will be more likely to get worse."* Similarly, one student from S23 wrote, *"[m]aking decisions when facing uncertainty is a complicated process…"*, and another wrote, *"[t]his exercise certainly motivates better more precise climate modeling, as if we can remove a lot of uncertainty, we can make much more efficient decisions to mitigate risk."*

Additional themes and words that emerged, especially in S23, were "Global Efforts", "investment", and "protection". One student in S23 wrote, *"[o]verall, this game made me understand that climate change adaptation in any country is a collective effort of different states and provinces as well as local government and it is extremely crucial to encourage knowledge sharing, resource sharing and regional collaboration and cooperation while tackling climate change issues."* This theme of global efforts was further highlighted in S23 by students' willingness to allocate the majority of robust options (6 of 8) to the nations rather than provinces. Lastly, the prompt given to students was intended to collect information about students' emotions. One student in S22 noted that "*[w]e cannot foresee the possibility of drought and flood, which makes me more nervous"* and one student in S23 wrote *"I was anxious about my choices because there was not much certainty."* While common keywords such as anxiety were more expected, keywords such as anger were not as expected. These additional themes and keywords pointed to the global perspective and social/psychological aspects of playing the D4tD game and making decisions under uncertainty.

4.1 Limitations

Assessment of the impact of this serious game on student learning was subject to limitations, some of which also constrained the generalizability of findings beyond the context of this university and department. Firstly, only water-related climate challenges were considered as part of the game. In order to keep the game as simple as possible, other impacts of climate

change, such as the urban heat island effect or sea level rise were not included. However, decision makers across the world must consider many different types of hazards, which can also be compounded and make decision making even more difficult. Secondly, the analyses were dependent on sample size, student reporting, and student interpretation of prompts and/or assignments. For the qualitative analysis, the small sample size and the nature of the data collected prevented authors from delving deep into the underlying reasons or mechanisms behind students' emotions, while the quantitative analysis was dependent on students reporting their points accurately at the end of each decade. For the qualitative analysis, instructors did not have control over participants' interpretation of the prompt or how they framed their responses, which may have limited the analysis. Although instructors tried to minimize bias by informing students that grading was solely based on completion, students might have provided responses they believed were expected, rather than their genuine emotions and understanding. In addition, although the general reflection indicated they liked playing the game in the class, students did not provide any constructive criticism about the game or its role in their learning.

5.0 Conclusions

These results attest to the benefit of the Decisions for the Decade (D4tD) game as one way to improve student understanding of uncertainty and robust decision making for climate change adaptation and planning in this university and departmental context. At the provincial level, quantitative analysis showed that the observed decrease in the number of prosperity points or increase in the number of provinces with at least one crisis tended to occur when the method used to simulate precipitation was more uncertain and students were unable to use probability to help make decisions. Similar trends were observed at the national level, but students seemed to generally be more cautious when making collective national decisions than when making individual provincial decisions, choosing the 'Robust Option' more frequently at the national level. This demonstrates the benefits of collective learning and decision making for climate change adaptation and robust decision making under deep uncertainty. In the qualitative analysis, many of the common themes and keywords reported in student responses were used by the instructors as part of the game description and explanation, but student responses included additional keywords highlighting their growing understanding about uncertainty and robust decision making. The qualitative analysis of the student responses from two separate cohorts in terms of word count, thematic patterns, and their respective frequencies offered insights into the evolving perspectives, concerns, and areas of focus among the students over the course of the two academic years.

6.0 Future Work

The following suggestions can be used to improve game play in future classes. More standardization of the way that the game is played, for example, the sequence of the methods used to simulate precipitation in each decade (see Table 1), the type of cone that is used for the cone method, or how many robust options are offered to each cohort (see Table 2), can further reduce the variability among future cohorts. This analysis also highlights the importance of selecting appropriate quantitative metrics to assess the success of the game in achieving predetermined goals. The two complementary metrics used for quantitative analysis (number of prosperity points and increase in the number of provinces/nations with at least one crisis) demonstrated that using more than one metric seems ideal, and future work could identify other complementary metrics that would be easy for students to report. The instructors plan to continue playing this game and collecting data to analyze results for future cohorts, facilitating the identification of any new and emerging patterns that may be useful to educators beyond this university and departmental context.

7.0 Acknowledgments

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9.0 Appendix

Game play instructions and PowerPoint presentation used to introduce the game to students.

DECISIONS FOR THE DECADE:
A Game on Deep Uncertainty and Robust Decision Making

THE WORLD BANK

RED CROSS/RED CRESCENT CLIMATE CENTRE

International Federation of Red Cross and Red Crescent Societies

The Netherlands Red Cross

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

1. INTRODUCTION

The World Bank Office of the Chief Economist for the Climate Change Global Practice Group has been developing a toolkit of analytical and experiential products to acculturate World Bank staff and clients to new methods and paradigms for dealing with "deep uncertainty". Deep uncertainty refers to those situations in which analysts do not know, or cannot agree on (i) models that relate key forces that shape the future, (ii) probability distributions of key variables and parameters in these models, and/or (iii) the value of alternative outcomes (Hallegatte et al. 2012, see http://elibrary.worldbank.org/doi/book/10.1596/1813-9450-6193).

Deep uncertainty is pervasive, challenging decision makers around the world. Yet such uncertainty is difficult to acknowledge, understand, and manage. We are more comfortable facing risks we can quantify, and solving problems for which we have familiar well-honed tools. Under such pressures, robust decisions can be elusive. Sociopolitical expectations compound this problem: Analysts and decision makers routinely face pressures to demonstrate that a decision is risk-free. Political and cultural expediency press them to ignore rather than acknowledge uncertainty and thus present their decision as advantageous and certain.

It is rare for decision makers to seek out and promote robust decisions, even though in practice it may be easier to build consensus around them. As the world's largest development lending institution, the World Bank grapples with these challenges daily. The CCG Chief Economist's team seeks to illuminate the issue by:

- In the long run, seeking to mainstream new approaches for robust decision making (RDM) into the design and implementation of WB projects, as well as into the analytical methods and policy processes of clients.
- In the short-run, educating various audiences about deep uncertainty, how managing uncertainty differs from managing risk, and what tools are available to support RDM.

In the past, researchers and practitioners have relied largely on lectures and publications to communicate to decision makers both the problem of deep uncertainty and the concept of robustness as a way to manage it. This unidirectional format has the shortcomings of most prevalent forms of engagement. Unfortunately, the cost of failing to successfully reach the target audience is high. Governments and institutions around the world commit to spend billions of dollars annually in long-term investments for which managing deep uncertainty is essential. Climate change looms large as a new kind of emergent threat that cannot be managed with traditional approaches to risk management based on refining probabilities and projections.

In the past year, the Office of the Chief Economist has turned to serious games as a way to enable stakeholders to experience and come to grips with these challenges first hand. With generous funding from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the World Bank invited the Red Cross / Red Crescent Climate Centre to collaborate with the Chief Economist's team to develop a game for achieving three objectives:

1. Demonstrate to players the necessity of balancing the value of knowledge with the risks arising from overconfidence in knowledge, either when (a) assuming that a modeled probability distribution function (PDF) is the real-world PDF; or (b) assuming that it is always possible to assess the PDF, even for unknown or ill-known processes.
2. Introduce players to alternative decision-making approaches in a context of uncertainty (i.e. when the PDF cannot be determined) and demonstrate that these approaches are both common in everyday life and no more complex than standard probabilistic/optimization approaches.
3. Demonstrate that the robustness of a policy/intervention portfolio depends on assessing the level of uncertainty (including the appropriate degree of confidence in knowledge).

The game principally targets development practitioners (e.g. World Bank task-team leaders) and government technical experts. It was designed in the context of a planned daylong RDM workshop and can be delivered between approximately 2 to 3 hours for gameplay and debrief discussion. The chief result of this collaboration with the Climate Centre is "Decisions for the Decade".

2. BRIEF DESCRIPTION OF "DECISIONS FOR THE DECADE"

In *Decisions for the Decade*, each participant is a provincial governor and small teams make up the governing body of a nation. Central to the game experience is that participants do not initially recognize the likelihood of disasters as deeply uncertain and, like many decision makers in the real world, plan for the most likely disaster scenarios rather than for extreme events that can bring devastating outcomes.

All participants begin the game with a budget of ten beans (for a ten-year cycle), and seek to maximize the prosperity of their province and country by investing their budget in long-term development. However, floods and droughts can threaten this investment. The threat of extreme events is initially depicted by a six-sided die, introduced to players as the probability distribution function of precipitation based on the past record (a 1 represents a drought, a 6 a flood). Governors may choose to allocate a portion of their budget to disaster protection to avoid humanitarian crises – investing one bean offers protection against one extreme event. If each extreme event that occurs during ten rolls of the dice is matched by a corresponding protection investment, their development investment leads to prosperity, and the player will accrue *Prosperity Points*. However, if they incur a crisis (for example more floods occur than flood protection beans invested) all of their development investment for the decade is diverted to crisis management, and the prosperity of their province does not increase.

After three ten-year cycles, the winning provinces are those that have accrued the most Prosperity Points while having simultaneously avoided crises. Importantly, unknown to the players, the object representing rainfall is changed at the start of each new decade: the six-sided die is first replaced by an eight-sided die (a flood occurs if the roll is 6 or more: i.e. a probability of 3/8, or more than double the original probability of 1/6); and then by a truncated cone that is nearly impossible to understand in terms of the chances of falling on the big base (representing floods) or the small base (representing droughts) vs. landing on its side (good conditions). As with actual climate projections for much of the world, different players formulate very different interpretations of whether future conditions are likely to become wetter or drier, and as a team they have a chance to reflect on how to manage the emergent deep uncertainty.

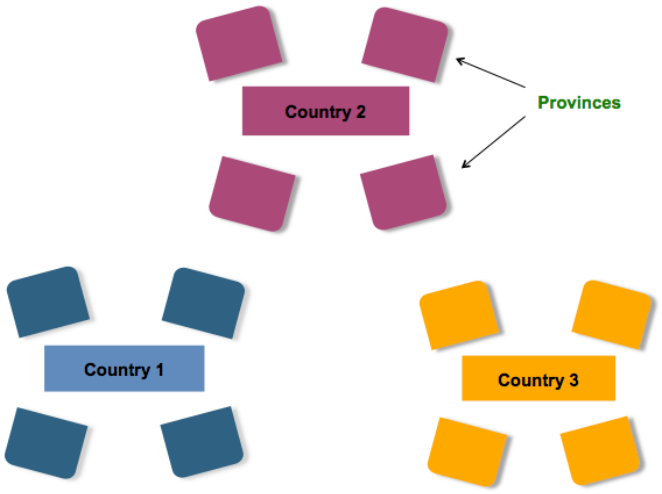
The game offers participants robust options, which are insensitive to the probabilities of disasters, but which also have a lower payout than would an optimized investment if these probabilities were known. In other words, the robust options work well no matter what the disaster regime, but they may not be the best in any single predicted regime. The game further invites urgency, as scientific information changes during game play, and conflict, as certain decisions require consensus in the face of diverging beliefs about the scientific information.

3. GAME RULES

Setup and Materials

The activity is designed to enable the active and meaningful participation of 8 to 60 people. It requires teams of 4 to 6 participants (each representing a 'provincial governor) sitting around a table representing the country. The game can be run by just one facilitator, although it can be beneficial to have a support team of 2-3 facilitation assistants to support the set up, gameplay and debriefing.

The total duration of gameplay plus debriefing can range between 45 minutes and 2 hours, depending on total number of participants, facilitator's experience, and desired depth of discussion during both gameplay and debriefing.

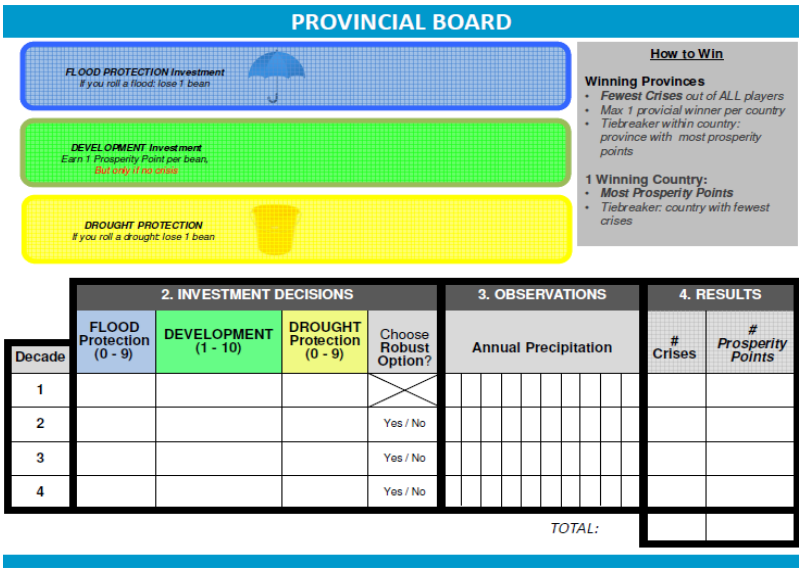


Each player requires:

- 10 beans
- A player board

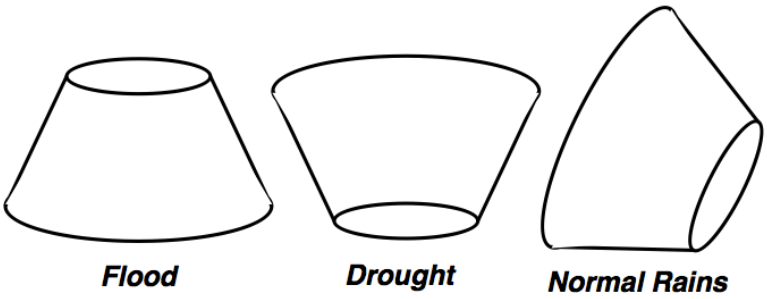
Each team of 4 to 6 players sits around a table and requires:

- 10 beans
- A team board
- About 15 red stones, representing "crises"
- A normal, six-sided die to represent normal rainfall. A value of 1 represents drought; a 6 represents a flood.
- A special, eight-sided die (available in game stores). A value of 1 represents drought; a 6 or more represents a flood.



The facilitator requires:

- Set of 'robust investment' cards: about one for every 3 players
- A 'cone of uncertainty'
- Powerpoint file to support explanation of rules
- Prizes: one small prize per team (for best province in each country) plus one larger prize (for best country)



Game Flow

The powerpoint file provided as an attachment includes notes in most slides, with proposed wording to help the facilitator explain the rules and introduce the different elements of the game as the decades progress – all in the context of a broader workshop about deep uncertainty and robust decision making.

During the introduction, the facilitator highlights that "Decisions for the Decade" is an intensely interactive game designed to support learning and dialogue about key aspects of long-term investments under uncertainty. The game is a simplified representation of reality (no challenging of rules please), and involves the links between limited information, rapid decisions, and consequences. The activity becomes increasingly fast-paced, and designed to take participants to the edge of tolerable confusion in a context of serious fun.

Each player takes on the role of a provincial governor. All participants share a simple and noble goal: to create a prosperous province and nation over the coming decades. The winning country will be the table of 4-6 players with the most prosperity points (if there's a tie, the country with the fewest crises wins). Within each country, the winning province will be the player with no crises that has the most prosperity points. There are prizes for the winners.

The vision can be challenged by the risk of devastating floods and droughts. If in any given decade the number of extreme events surpasses the investments in flood or drought protection, all development is lost and humanitarian crises occur. All provincial governors with one or more crises will likely be labeled as losers by their suffering populations…

The game is played in four cycles, each representing a decade – or until time runs out. Within each decade, there is a sequence of four phases: *Scientific information, Decisions, Observations,* and *Results.*

1. Scientific Information: Facilitator describes of what is known about probabilities of extreme rainfall for the coming decade. The first decade is a practice cycle using the six sided die ("normal rains based on the past record of precipitation"). The second decade also uses the six sided die, and introduces the "robust option" card. The third decade imposes changing climate risks (in the form the eight-sided die, introduced after year 2). The fourth and final decade involves the "cone of uncertainty" to elicit different estimations of flood and drought probabilities among players, thus allowing for the emergence of deep uncertainty and the stronger consideration of the robust option.

2. Decisions: First, each provincial government player individually decides how to invest their ten beans – no consultation allowed. The beans can be allocated to protective investments (flood or drought), productive/development investments, or the robust option. Staring in the second decade, the facilitator introduces the "robust option" cards, which represent a climate-independent investment that regardless of observed rainfall offers a guaranteed quantity of prosperity points in exchange for ten beans (the facilitator announces the 'prosperity points' benefits of these cards each decade at his or her discretion – a value of 2 or 3 is recommended). Players without the "robust option" must allocate at least one bean to development investment. Then all players in a table collectively make investment decisions for the country (default option is that all beans are allocated to "development": only if there's consensus can any other choice be made). The facilitator imposes a firm, tight deadline for these two investment stages. Players document their individual and collective choices on the corresponding board.

3. Observations: After the investment deadline, each team rolls the rains ten consecutive times, representing ten years. Every time a flood happens, provinces and countries without the "robust option" must remove a "flood protection" bean from its place and relocate it to the 'used beans' sector of their board. Similarly, every time a drought happens, players without the "robust option" must remove a "drought protection" bean. Whenever an extreme event happens and no protective beans are available, a "crisis" occurs: All development beans are lost, and a red stone must be placed on the board. If no crisis takes place by the end of the decade, the beans allocated to "development" are counted as 'prosperity points'.

4. Results: Players document their individual and collective outcomes on the corresponding board, and briefly discuss the links between information, decisions and consequences. When relevant, the facilitator invites players to share observed events, insights or questions.

Game end: Upon the facilitator's decision to end the game, the winning country and provinces are determined, prizes are given out, and a debriefing begins to elicit emotions and insights – preferably regarding uncertainty and robust decision making. Given the goals of the World Bank SDNCE, the best moment to end the game is during the fourth decade, right after the "decisions" phase (before tossing the cone of uncertainty). This is one of the moments of most intense thinking and reflection about the challenges of estimating probabilities in a context of deep uncertainty. It allows for participants to be left with the vivid feeling of deep uncertainty, enabling richer discussion during debriefing. After the end of the game, the facilitator can share any additional insights and thank participants for their involvement.

4. GAMEPLAY SESSIONS AND PUBLICATIONS

"Decisions for the Decade" has already been played with a variety of audiences. In December 2013 it was used in Peru to launch a collaboration with stakeholders on using Robust Decision Making to ensure long-term water security. Participants included diverse backgrounds and interests, including technical staff from the water utility, officials from the National Water Authority, leaders at the private hydropower company, and representatives from local NGOs. In January 2014, it was used in Colombo, Sri Lanka at a kickoff workshop for a master planning effort on flood risk and wetland management; it was also used at a meeting of lead coordinating authors of the

Integovernmental Panel on Climate Change (IPCC), where a modified version of the game incorporated the actual graphs of the IPCC Summary for Policy Makers to integrate risk and uncertainty considerations in investment decisions.

Feedback from the game sessions reveals that this intensely interactive approach whets participants' appetites – intellectually and emotionally – for an in-depth presentation and discussion on deep uncertainties and how to manage them in real world settings. The game primes participants to think about the unknown, to challenge each other on assumptions about the future, and to explore how different types of analyses – in particular those that focus on robustness -- can help address the changing challenges they face.

As one example, a participant in one gameplay session remarked, "At first I thought it was very unfair to change the probabilities of the disasters, but afterwards, I realized that this happens in the real world all the time. We have to plan for surprises." At another event, a participant noted, "Without the game, we don't get a feeling of uncertainty. We always make decisions based on the past. This is not the correct approach," and, in reference to their mission of flood risk management, added, "We need to know what the robust flood risk actions are for us!"

Decisions for the Decade has been included as a case study in the manuscript entitled "Loss and damage in a changing climate: Games for learning and dialogue that link HFA and UNFCCC", coauthored by Pablo Suarez and Nidhi Kalra and submitted as an input paper to the UNISDR Global Assessment Report on Disaster Risk Reduction 2015 for the GAR Thematic Research Area 17 on adaptation and mitigation in the context of the HFA (see Annex I). An additional manuscript is currently in preparation for *Nature Climate Change.*

The "Decisions for the Decade" game was designed by Pablo Suarez and Janot Mendler de Suarez (Red Cross / Red Crescent Climate Centre) for the World Bank Chief Economist for Sustainable Development/ Climate Change Global Practice and the Green Growth Knowledge Platform, with support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Decisions for the Decade

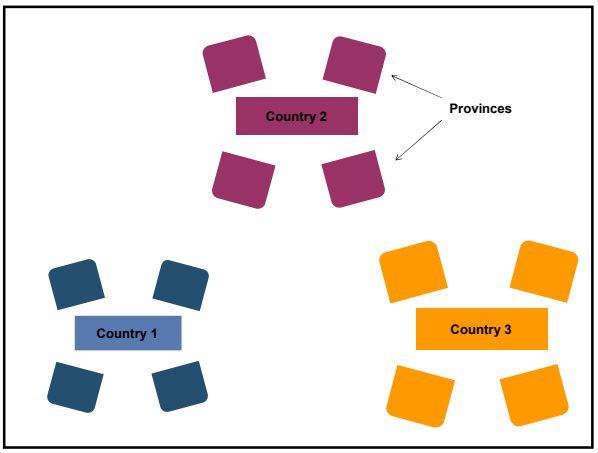
How do we make smart long-term decisions?

All Participate
(...expect confusion...)

THE WORLD BANK

RED CROSS/RED CRESCENT CLIMATE CENTRE

1



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3

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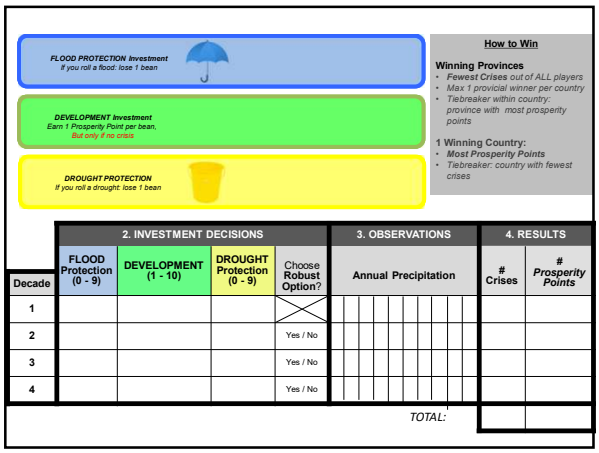
5

BASIC RULES

1. **Simplification of reality**
   No challenging the rules!
2. **Decisions are individual**
   No consulting with others on Provincial Decisions
   Do collaborate during National Decisions
3. **We will play 4 decades of decision making**
   Each round is 10 years

6



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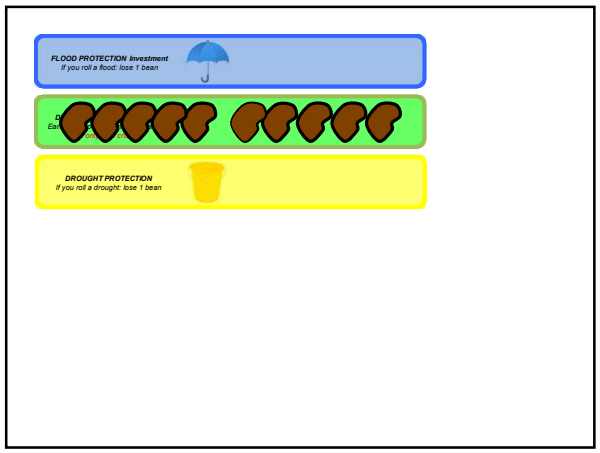

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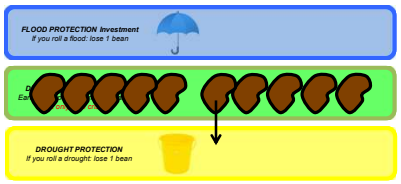
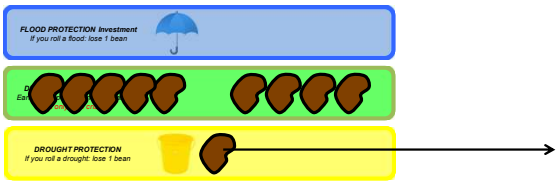


Let's protect against 1 drought…

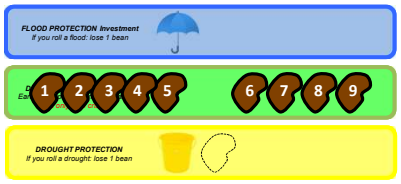
9



Let's protect against 1 drought…

When a drought occurs, use a protection bean…

10



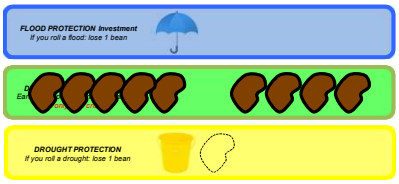
Let's protect against 1 drought…

When a drought occurs, use a protection bean…

If just 1 drought occurs…

…we get 9 Prosperity Points!

11



But, what if we had a second drought?

Not enough protection…

…means a humanitarian <u>crisis</u>

…and <u>0 prosperity points!</u>

Each shortage of protection is a new crisis!

12

1. Scientific Information

Probabilities, Predictions, Etc.

2. Decision

Your 10-Year Investment in Development and Protection

3. Observations

Rains, Teammate Decisions

4. Results

Crisis….or Prosperity Points?

13

1. Scientific Information

Probabilities, Predictions, Etc.

2. Decision

Your 10-Year Investment in Development and Protection

3. Observations

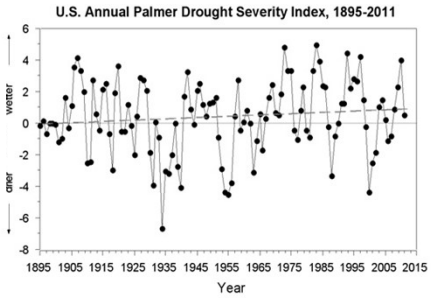
Rains, Teammate Decisions

4. Results

Crisis….or Prosperity Points?

14

1. SCIENTIFIC INFORMATION



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16

1. Scientific Information

Probabilities, Predictions, Etc.

2. Decision

Your 10-Year Investment in Development and Protection

3. Observations

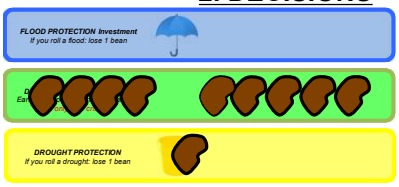
Rains, Teammate Decisions

4. Results

Crisis….or Prosperity Points?

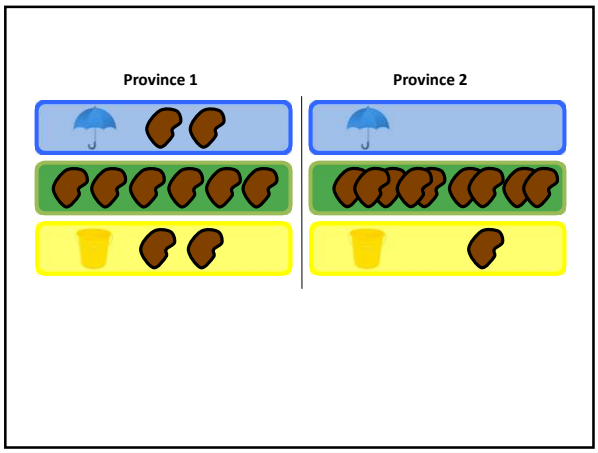
17

2. DECISIONS



Decade	2. INVESTMENT DECISIONS: FLOOD Protection (0 - 9)	DEVELOPMENT (1 - 10)	DROUGHT Protection (0 - 9)	Choose Robust Option?	3. OBSERVATIONS: Annual Precipitation	4. RESULTS: # Crises	# Prosperity Points
1	0	9	1				
2				Yes / No			
3				Yes / No			
4				Yes / No			
				TOTAL:			

18



19

National and Provincial Decisions

1. Provincial decisions are independent

2. National decisions require teamwork
   - Default is to invest in development
   - Consensus to invest in protection

20

1. Scientific Information

Probabilities, Predictions, Etc.

2. Decision

Your 10-Year Investment in Development and Protection

3. Observations

Rains, Teammate Decisions

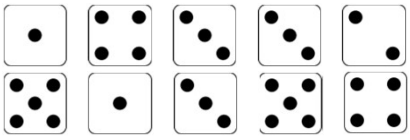
4. Results

Crisis….or Prosperity Points?

21

3. OBSERVATIONS

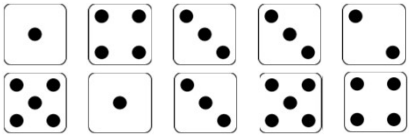
Ten years of rainfall occur



22

3. OBSERVATIONS

Ten years of rainfall occur



Decade	2. INVESTMENT DECISIONS: FLOOD Protection (0 - 9)	DEVELOPMENT (1 - 10)	DROUGHT Protection (0 - 9)	Choose Robust Option?	3. OBSERVATIONS: Annual Precipitation	4. RESULTS: # Crises	# *Prosperity Points*
1	0	9	1		1, 4, 5, 3, 2, 5, 1, 3, 5, 4		
2				Yes / No			
3				Yes / No			
4				Yes / No			
				TOTAL:			

23

1. Scientific Information

Probabilities, Predictions, Etc.

2. Decision

Your 10-Year Investment in Development and Protection

3. Observations

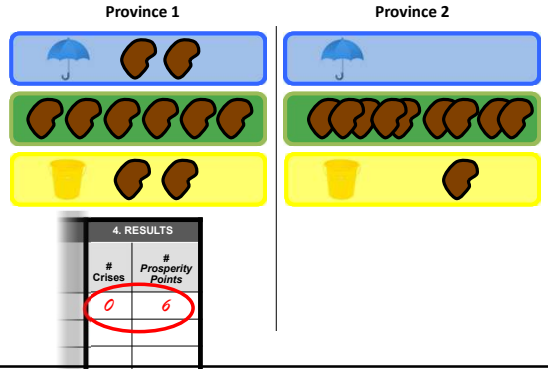
Rains, Teammate Decisions

4. Results

Crisis….or Prosperity Points?

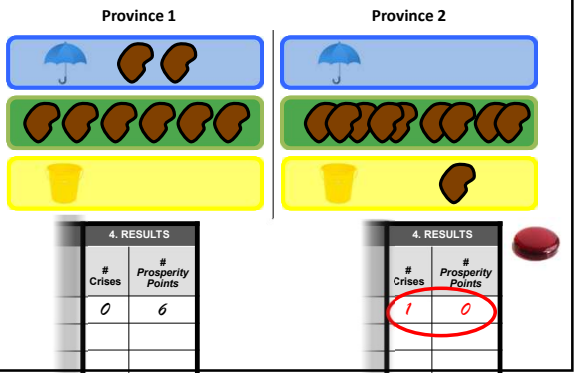
24

4. RESULTS



25

4. RESULTS



26

Winners & Losers

Provincial Losers:
Anyone with a CRISIS…(1 or more)
(If everyone has a crises then anyone with 2+, etc.)

Winning Province *in Each Country:*
No crises! (Or fewest crises in the room)
Most Prosperity Points

1 Winning Country:
Most Prosperity Points
Tiebreaker: country with fewest crises

27

Let's Play!!!

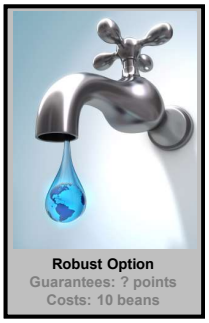
28

1. SCIENTIFIC INFORMATION
Historical Rainfall

= Flood

= Drought

29



Robust Option
Guarantees: ? points
Costs: 10 beans

30

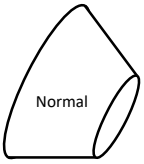
Have you heard about…CLIMATE CHANGE?

6 7 8 = Flood

1 = Drought

31

We have a NEW MODEL for climate change...



32

Final Results: Decades 1-3 ONLY

	2. INVESTMENT DECISIONS				3. OBSERVATIONS	4. RESULTS	
Decade	FLOOD Protection (0 - 9)	DEVELOPMENT (1 - 10)	DROUGHT Protection (0 - 9)	Choose Robust Option?	Annual Precipitation	# Crises	# Prosperity Points
1							
2				Yes / No			
3				Yes / No			
4				Yes / No			
				TOTAL:			

33

RED CROSS/RED CRESCENT CLIMATE CENTRE

International Federation of Red Cross and Red Crescent Societies

The Netherlands Red Cross

This game was designed by Pablo Suarez and Janot Mendler de Suarez (Red Cross / Red Crescent Climate Centre) for the World Bank Chief Economist for Sustainable Development, with additional support from the American Red Cross and CDKN.

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PLATEAU NATIONAL

PROTECTION INONDATIONS
Si vous obtenez une inondation, vous perdez 1 haricot

Investissement de DEVELOPPEMENT
Gagnez 1 Point de Prospérité par haricot investit
Mais seulement si vous n'avez pas de crises

PROTECTION SECHERESSE
Si vous obtenez une sécheresse, vous perdez 1 haricot

Comment Gagner

Provinces Gagnantes
- *Le moins de crises parmi tous les joueurs*
- *Max 1 gagnant provincial par pays*
- *Bris d'égalité au sein du pays: province avec le plus de points de prospérité*

1 Pays Gagnant
- *Pays avec le plus de Points de Prospérité*
- *Bris d'égalité: pays avec le moins de crises*

	2. INVESTMENT DECISIONS				3. OBSERVATIONS	4. RESULTS	
Decade	FLOOD Protection (0 - 9)	DEVELOPMENT (1 - 10)	DROUGHT Protection (0 - 9)	Choose Robust Option?	Annual Precipitation	# Crises	# Prosperity Points
1							
2				Yes / No			
3				Yes / No			
4				Yes / No			
				TOTAL:			

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Debrief Questions/Observations

- Each country, discuss and share with us 1 emotion you felt playing the game, and 1 observation. Keep it brief.
- How many people started out with ~2 beans in drought or flood protection? That is the average number of droughts or floods that would occur. What happens when we protect to the average? (Caught by extremes – outcomes of disaster are… disastrous. Asymmetric results.)
- How do we resolve conflict? By meeting in the middle. Which also often leaves us less than protected.
- What elements of the game resemble the real world?
- In this game, we only talked about climate uncertainty. What other sources of uncertainty affect the decisions you face?