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Abstract

A decision is an act or event of decision taking. Decision making always includes decision taking, the latter not involving significant exchanges with non-deciding agents. A decision outcome is a piece of storable information constituting the result of a decision. Decision outcomes are typed, for instance: plan, command, assertion, or boolean reply to a question. A decision effect is any consequence of putting a decision outcome into effect. Decision outcomes must be expected by the decider to lead to certain decision effects, by way of their being put into effect. The availability of a model or of a theory of the causal chain leading from a decision outcome to one or more decision effects is assumed for the decision taker, otherwise the decision outcome is merely an utterance. Decision effectiveness measures the decision effects against objectives meant to be served with the decision.

Decision taking is positioned amidst many similar notions including: decision making, decision process, decision making process, decision process making, decision engineering, decision progression, and decision progression production. Decision making is operationally defined as an informatics related activity consisting of the production of progressions from threads, thus casting decision making competence as an informatics competence. Short-circuit logic underlies the production of decision making progressions from instruction sequences that codify prepared decision making processes. Decision taking can constitute the primary task of dedicated agents. Human agents in such roles are professional decision takers. Multi-threading is essential for the professional decision taker.

1 Introduction

The objective of this paper is to conceptualize the notion of a decision by making use of a number of techniques and concepts from informatics. In particular a decision will be defined as a tuple of components of various types, which is a

*Author's email address: j.a.bergstra@uva.nl. This paper has been written in the context of the NWO Jaquard project Symbiosis which focuses on software asset outsourcing and on IT outsourcing in general. Indeed, the objective to analyze outsourcing decisions (see [27]) and follow-up outsourcing decisions (see [4]) justifies a preparatory investigation of decision making in general.

common style of introducing a concept in informatics.[1] This leads to a so-called constructing definition of "decision" in the terminology of [9]. I will propose to view decision making as an informatics competence for the simple reason that the decision outcome primarily constitutes a piece of information. I will use the terminology as well as the definitions of [12] concerning competence and ability. That terminology includes the notions of a (decision making) framework competence, a community confirmed competence, an evidence based ability, a competence profile, and of a conjectural ability.

Readers who have read and reflected upon Sections 2 and 3 below, will be said to have acquired a decision taking framework conpetence. This puts them in the intended audience for taking notice of the constructing definition of decision as given in Section 4, as well as the subsequent theory development, According to [12] a competence profile consists of a number of community confirmed competences, which may be but need not be evidence based, possibly augmented with one or more evidence based abilities lacking community confirmation, and possibly augmented with one or more conjectural abilities, which are lacking by definition of being conjectural both an evidence base and community confirmation. The conceptualization of "decision" below, together with some of its consequences qualifies as a "theory of decision taking", which is admittedly incomplete and of a limited scope. In addition I will provide specific proposals concerning conjectural abilities concerning about taking which can be considered plausible consequences of a person's awareness this theory.

In [43] the observation is made that decision making research mainly stands on two feet: description and prescription.[2] Description calls for observation and invites the development of theory which may or may not be confirmed by observation. Prescription may lead to improved behaviors not previously observed, or to a more frequent occurrence of best practice. Even prescription can be analyzed from the perspective of a theoretical framework that supposedly explains why prescribed patterns (of decision making) are to be preferred. Nutt [43] indicates that action theory combines description and prescription.

I will pursue construction as an alternative approach to concept analysis which is standing on an equal footing with description and prescription. Decision is thought of as an idealized concept, found by means of a constructing definition, independent of any empirical observation, and without any intention for being prescriptive. The constructing definition of decision can be used by readers who are willing to forget about their prior intuition about decision, and to reconsider the notion in such a way that unexpected consequences may result, that is some events that were not thought of as decisions may turn out to be regarded as decisions and conversely.

[1] For instance although the notion of an automaton sounds familiar to most people, in informatics an automaton will be defined to constitute a tuple of interrelated items of various types.

[2] A similar dichotomy underlies the survey [44]. That paper distinguishes descriptive and normative realms of (business) ethical decision making.

1.1 Getting started on decisions and decision making

Writing a paper from first principles on decisions and decision making is a problematic objective given the amazing size and scope of the existing literature on these themes. In [6] I have commented at length on this kind of difficulty, in the context of writing on money. Similar comments may be brought forward in the present context, and instead of repeating that part of [6] I only cite its existence. A conclusion drawn in [6] that a best effort to write about a subject is legitimate even if guarantees of novelty cannot be provided due to the sheer size of the prior art. In addition guidelines on how to work properly in such circumstances are put forward. Compliance with these demanding guidelines is not an easy matter, however, an experience I made when writing on the concept of money in [6], and again when writing on a specific non-classical logic in [8]. In [7] I made an attempt to explain why it is plausible to test control code, a position which I could not find anywhere in the massive literature on software testing which invariably takes the rational of testing for granted. Confronted with the difficulty to grasp a massive literature on software testing, I made use of what I termed an informal logic. But I failed to notice that the notion of an informal logic is quite well-established already and that it has an entire journal devoted to it, something which clearly should have been made mention of in the same paper. References to papers on informal logic were subsequently provided in [8]. However, the guidelines from [6] just mentioned imply that a new version of [7] should have been produced, taking these references (say [47, 59, 60]) adequately into account. Doing so, however, would violate the document uploading rules of the repository `www.arXiv.org` which imply that only major modifications of a paper justify posting new versions. That leaves one with the question when inserting a previously missed reference is a substantial change of a paper. That question seems not to have a general answer.

In spite of the existence of a very extensive literature on decisions and decision making I will not start this work with giving a survey on decisions and decision making for the simple reason that doing so properly is a formidable challenge in itself and because it seems not to be a prerequisite for this paper.

1.2 Organization of the paper

In Section 2 a number of issues are raised each related to decision. In Section 3, preliminary design decisions are developed concerning a definition of decision. Section 4 contains the constructing definition of decision. Subsequently and on the basis of that definition a number of derived concepts is developed and various ramifications of the definition are considered. In Section 5 initial steps towards the development of a theory of decision taking are made. Decision taking theory includes decision quality, decision free management, implementation of decision mechanisms, decision making models, levels of decision making and taking, and decision taking in a structured hierarchy. Following the conceptual structure of competences and abilities of [12] a survey is given of conjectural abilities on decision taking which I believe to result from taking the constructing definition

and other aspects of decision taking theory into account. Finally I return to the title of the paper by listing various informatics perspectives on decision taking.

2 Preparatory analysis of decision

Many aspects concerning the common intuition of a decision need to be contemplated before writing a constructing definition can take off. The constructing definition to be developed will take some aspects into account. In this Section I will consider the notion of a decision from different angles thus closing in on a preliminary survey of issues that may need to be covered by a definition of decision.

2.1 Primitive and non-primitive concepts

Constructing definitions, by definition, do not produce primitive concepts, that is concepts requiring no further constructing definition. But every construction definition will ultimately rely on the use of primitive concepts if its author is committed to avoiding an infinite regress. These matters will first be considered in some detail.

2.1.1 Decision: not a primitive concept

Definitions of decision are useless if decision is a primitive concept that cannot be reduced in a useful way to other more primitive concepts. For instance "meaning" might be considered a primitive concept, if one appreciates that defining the meaning of meaning without somehow making use of that very notion is difficult. Similarly the word important is not easily defined without already knowing what it means. I hold that the term choice is primitive in the same sense.

If one assumes that a decision is a choice that matters for the future of the agent making the choice, then decision is what takes place if an agent (decider) makes a choice. If the agent is human, and if one believes in the existence of a free will, one may insist that the agent's decision is a manifestation (or an expression) of the agent's free will.

I will assume a much larger distance between decision and choice, however, leaving choice a primitive concept which may be explained in terms of mathematical theories of an axiomatic nature, such as modal logic, process algebra (see [3]), whereas decision is a constructed notion that admits a reduction to (decomposition in terms of) a collection of primitive elements. In specific cases, the occurrence of choice may be among these elements.

2.1.2 Decision: not an almost primitive concept

Suppose that decision is identified with choice in the sense that each decision is a choice but not necessarily the other way around. In that case decision is not primitive because it can be reduced to another primitive concept. But the

reduction is trivial, as it is a mere renaming which takes into account some additional requirements. Let a concept be considered almost primitive if its reduction to a primitive concept is a mere renaming which may express that some additional requirements have been taken into account. Thus occasion (used car) is an example of an almost primitive concept, assuming that car is a primitive concept. Then one may ask: is decision an almost primitive concept. I propose that this question has a negative answer.

2.1.3 Decision outcome: an almost primitive concept

The existence of a decision requires more than the presence of the outcome of some process that must have involved a choice. Concerning the outcome a precise terminology will be needed. In [48] one finds in proposition 4 " a considerable gap usually exists between the formulated decision and its implementation". This corresponds with the terminology proposed in this paper as follows: decision outcome will be used instead of formulated decision, and effect is used instead of implementation. A decision outcome is a result, and the term result will not be specified any further. As a consequence "decision outcome" is taken to be an almost primitive concept.

2.2 Decision versus decisive action

Some actions seem to require preparatory decisions and some decisions seem to be of decisive influence. Neither is by necessity the case, however. This leads to the following observations.

2.2.1 Postulated decisions considered vacuous

In [40] one finds decision as an indication of an activity for which it is unlikely that it can be performed without a decision having been taken in advance in such a way that putting its outcome into effect involves or implies the mentioned activity, for instance the decision to state one's critical viewpoint in a public meeting. This use of the term decision, a postulated decision, will be avoided below because it will lead to confusion and ambiguity. Can one talk about the early retirement decision, or the coffee making decision, or the emergency evacuation decision. In the latter case one might be tempted to state under certain conditions that the emergency evacuation decision has not been properly taken to express the fact that there was no such decision although there should have been one.

The term emergency evacuation decision (that is the postulated decision assumed to have existed by an external observer of an emergency evacuation) is as problematic as the well-known top of a stack: what if the stack is empty. Then talking about its top postulates the existence of an object which fails to exist. I refer to[18] for an extensive discussion of notations for potentially non-existing objects which may also be applied if one insists on making use of postulated decisions.

2.2.2 Decision taking need not be decisive action

In [48] USA presidential decision is put forward as being part of a political process without decisive influence by itself. I will follow this view and assume that a decision need not be a decisive action, where a decisive action is characterized by being of major explanatory value in hindsight for the occurrence or non-occurrence of subsequent events. One may ask to what extent decisive action must be the consequence of decision taking. This question has become very prominent in political science, because of the fact that several very serious human rights violations in the 20th century, each of which which can be considered to comprise decisive action, seem not to have been preceded by a well-organized decision making process. Thus decisive action need not have been caused or preceded by a decision, not even if common language suggests the existence of a corresponding postulated decision. Indeed, the very notion of a postulated decision has been discarded already. Decisiveness cannot be assessed in real time, whereas decisionness (or degree of decisionality see 4.2) can.

In other words decision taking need not be the taking of decisive action, but it may be. For an action to be decisive it needs to have significant impact. One may intend an action to be decisive, or expect it to be, but only actions from the past can be qualified as having been decisive with some degree of certainty.

2.3 Deciding is decision taking

Decision taking represents the culmination of a decision making process. The more comprehensive decision process covers all of the decision making process, and in addition to that the activity needed, or applied, to facilitate or to bring about the decision making process. Decision making includes decision taking and in addition it comprises only that part of a decision process which directly influences decision outcomes.

Decision process making, refers to the activity of one or more agents who are the driving forces behind a decision process. Decision process making can be either internal or external. In the latter case I will speak of external decision process management, which includes external decision process making consultancy. A decision process making agent manages or organizes a decision process. A decision process may contain actions many of which are connected with the communication between agents who are directly or indirectly involved in the decision. A decision process may often be considered the putting into effect of a specific protocol, meant for a particular kind of decision. This putting into effect may be a multi-threaded concurrent activity driven by several agents, among which the decision takers, various decision makers, and some decision process assistants.

The picture I will suggest is that systematic (perhaps professional) decision taking is embedded in equally systematic decision making. Decision making requires control both in terms of putting protocols into effect and in terms of protocol design. Meta decision taking may be coined for taking decisions that occur within these tasks. Perhaps a better phrase is: decision process planning

and running. This functionality is responsible for the concurrent running of decision threads, as well as for adequate thread creation.

2.3.1 Alternatives to a decision, for an agent

Deciding is always an action that exists in a context where agents have other options. Besides taking a different decision, at least the following options can be distinguished:

administration Taking decisions that control the work of many other agents in a large variety of circumstances. Administration is the part of an organization or institution most focused on deciding. Administration includes policy making about decision process design and control.

networking Connecting to other agents with shared interests.

managing Telling agents ad groups of agents what to do, supporting their action, monitoring their action.

organizing Designing patterns of activity, and managing agents to act in these patterns.

political action Influencing individuals and groups towards certain ends. Political action has the flexibility of being less procedural than decision making.[3]

operation The lowest level of action where the work takes place, rarely interrupted by decision taking.

2.3.2 Alternative agent roles for a decision

Seen from the decision taking agent, decision taking may place with objectives in mind. Seen from the viewpoint of a decision a participant in decision taking may operate in different roles. Here are some options:

take An agent may be taking a decision, individually or as a member of a group with other agents.

influence An agent may (try to) influence the outcome of a decision.

await An agent may await a decision on which it fails to have any influence.

trigger An agent may cause a decision to be taken without having an influence on its outcome.

request An agent may ask for some decision to be taken.

[3] A political decision is a decision that takes place as a part of a political process, just as a business decision takes place in a business process.

2.3.3 Temporal aspects of decision

When speaking of decisions one may speak about future decisions about current decisions and about past one's. The fundamental flexibility of the concept of a decision is that it can be turned into abstract versions by leaving out information. So the following statements and questions may be meaningful.

who Who took (or will take) that (referring to substantial but incomplete information) decision.

why Why must that decision (that is a decision matching those specifications) be taken.

when When has that decision been taken, or when will that decision be taken.

cause Who (if anyone) took the decision to make that decision.

A decision ends a phase of indecision. A decision completes a phase where an audience of agents awaits the decision. A spontaneous and unexpected action by an agent is not considered a decision.

2.3.4 Can decision be freely defined?

When contemplating the various possible definitions of decision, I will entertain the hypothesis, if not phantasy, that while decision can be assigned a meaning with some degree of freedom, many other related terms like action, event, process, thread, result, etc. have been provided with a known meaning which is not going to be changed. Indeed, dissatisfaction about an account of decision may in principle be resolved by changing the meaning of many surrounding terms, but going ahead in that way is not the idea of giving a constructing definition of a notion.

The constructing definition of decision is developed on the basis of some preliminary understanding of decision, which is assumed to be available in advance. By taking notice of Sections 2 and 3 of this paper a reader may acquire so-called framework competence (see [12] for that notion) concerning the concept of decision which places him properly in the intended audience of the paper. In informatics the systematic definition of a concept labeled with seemingly familiar terms is often carried out under the heading of formalization, the use of that term being justified by the formal and mathematical appearance of texts. Besides formalization, however, the more important aspect of such definitions is to provide an existing intuition of a concept with much sharper, if not better, picture of that same concept. In giving the sharper definition a move may be made from a better picture of the (same) concept to an improved and modified view of the (adapted) concept, which is meant to replace the previous view.

As a mode of working this may be considered quite arbitrary indeed, but I see no alternative path.

2.4 Decision: like collision and unlike inscription

An overwhelming majority of papers on decision making has been written by authors who apparently assume that the meaning of the phrase "decision making" is unproblematic and is a matter requiring no explicit attention, at least not in their paper.[4] In this common understanding managers, consumers, politicians, and doctors, each make decisions, a task for which they may appreciate evidence based support, and moreover a task that admits detailed investigation.

I will assume that a decision is an act or event of deciding. Comparable cases are: an action is an act or event of acting, an explosion is an act or event of exploding, a collision is an act or event of colliding, a transmission is an act or event of transmitting, a computation is an act or event of computing, an execution is an act or event of executing. Participation is an act or event of participating.

In contrast to these examples, however, a permission is the outcome of an act or event of permitting, an edition is the outcome of an act or event of editing, a construction is the outcome of an act or event of constructing, a translation is the outcome of an act or event of translating, a transcription is the outcome of an act or event of transcribing, an inscription is the outcome of an act or event of inscribing, a definition is the outcome of an act or event of defining, and an emission often is the outcome of an act or event of emitting. A (problem) solution is the outcome of an act or event of problem solving. Although a simplification is often the outcome of an act or event of simplifying, a complication is usually not an act or event of complicating nor the outcome of such an act or event. Rather complication abbreviates the phrase "complicating factor". With pollution the situation is slightly more complex. Usually pollution is the outcome of a plurality of acts or events of polluting, but in some cases it refers to the consequences of a single event.

The terms prosecution, prevention, intuition, function, and prohibition do not fit either of the above schemes. Rather these terms stand for general structures or roles causing or enacting their instances. This kind of meaning is implausible for the term decision.

I propose that decision represents an act or event of deciding, rather than the outcome of such an act or event. Having made this "decision" concerning the meaning of "decision" in relation to "deciding", the phrase "decision outcome" is needed to refer to the outcome of a decision.[5] The decision outcome is an

[4] An example is [42] and also [33]. Another example is [37], and also the quite philosophical [28]. The style of writing of [37] is quite common: decision making occurs in situations, which may be considered opportunities for the decider. Such opportunities may be recognized and identified, and rather than thinking in terms of the generation of alternatives decision taking or making agents must focus on the generation and survey of values which determine what objectives are to be reached. In [37] DM stands out as a well-known and ubiquitous phenomenon admitting a flexible range of descriptions and analyses, without the risk that these make no sense because of a commitment to a narrow and specific definition of DM.

[5] The phrase decision outcome can be found in [32]. In [34] the decision outcome is referred to as the formal decision. I will not comply with that convention. In [22] a decision process, or equivalently, a decision-making process is said to end in the final making of a choice, or in the ultimate decision of choice.

object, perhaps a virtual one, which can last in time, whereas the decision itself is bound to agent, time and place and immediately becomes a part of history, often having its decision outcome as its most enduring historic account.[6]

Viewing a decision as an act or event of deciding, rather than as the outcome of such an act or event, cannot be maintained in every context. For instance a design decision is the outcome of an act or event of deciding about a design. A personal decision will usually refer to the outcome of an an act of deciding by a single individual. Decision making may involve additional steps which are not included in decision taking. Decision taking, provided it is distinguished from decision making in some particular case, constitutes a final and somehow highlighted stage of decision making, including the last act from which the decision outcome results.

2.4.1 Preliminary deliberation not required

In many descriptions of decision making (for instance [51]) it seems to be taken for granted of a decision that it concludes a phase of deliberation during which several different options (candidate decision outcomes) are compared and that the decision cumulates in making a choice between these options, the decision outcome being identical to the chosen decision outcome option. I see no need for this assumption, and I consider the existence of a deliberation phase to be optional. Of course it will be often the case that a decision involves making a choice between several options, and that the decision process involves some form of deliberation admitting a comparison of those options, but it is consistent to assume that the only alternative that has been considered in the process leading up to a particular decision concerning some subject was not to produce any decision (concerning that same subject matter, that is with the same or similar objectives) at all at the time of deciding.

Taking the meta-decision m_d to make a decision, say d concerning a subject s, with d not yet fully specified but with d's outcome in outcome type D, or with an outcome constrained by requirements R, is itself part of the very decision process of d. In order to state this matter properly one capable of speaking about a future decision as an action that complies with some specifications and which will be refined from these specifications during the decision process that leads up to that decision.

2.4.2 Decision ends a phase of indecision

I propose that each decision is preceded by a phase, however short in time, of indecision. That is some awareness of the need or opportunity that a certain decision is about to be taken must be present at least within the deciding agent. Thus a decision ends an episode of indecision. The phase of indecision may be

[6] Clearly an alternative is to have decision stand for what I proposed to be named a decision outcome. Then a phrase is needed for the act of taking a decision. No obvious candidate seems to be on offer, however. I will equate "a decision has been taken" with "a decision has taken place". I will also equate decision taking with deciding.

merely a postulated phenomenon, however, because its existence need not be provable in hindsight from documents or other records.

2.5 Atomicity and scope

The slogan that a decision is an act[7] or event of deciding cannot serve as a definition of a decision unless deciding has been defined. It only serves as a requirement on how to use words and phrases. A decision need not be atomic, it may split in several subsequent acts or events.[8] More specifically, a decision is a progression (see [20]) of acts or events that together qualify as representing an agent's activity of deciding.[9]

The decision taking process is a part of the decision making process, which may be imagined as the run of a decision making pipeline. A structured decision making process contains those steps of the workflow leading up to a decision which are explanatory for the final decision outcome.

Yet more comprehensive is the decision process. If a decision making process involves a meeting for taking a preliminary decision, the production of the inputs to that meeting will be part of the decision making process, while reserving the room and corresponding catering is part of the decision process but is not included in the decision making process. The decision process includes the actions and events of the decision making process together with all supporting and enabling activity, including catering, AV preparation, printing and copying, process control and monitoring, security, and transportation.

Decision process making (equivalently decision progression making) is the making of a progression of acts or events of a decision process, without participation in the decision making proper. Speaking in terms of progressions (or runs) I thus distinguish: decision taking progression (equals decision), decision making progression, and decision process progression.

Thus decision making ends with a decision (a decision taking progression) which produces a decision outcome. Decision taking is performed by the agent who is deciding. Decision making (equivalently: decision making progression) includes decision taking at its tail but comprises more preparatory steps if any are present. One may feel the need to speak of a decision making process making to denote the task of the agent who sees to it that decision making takes place,

[7] I will use act as a shorthand for activity.

[8] In [31] (p. 4) one finds: "..It is often hard to pinpoint the exact stage at which a decision is reached. more often than not, the decision comes about naturally during discussions, when the concensus seems to be reached among those whose judgement and opinion the executive seeks." In [57], however, a unique decision moment is said to exist. After that moment the decision cannot be taken again.

[9] This view is consistent with [52] although that paper seems to identify the decision process with the decision making process, and [52] proposes that a decision is a progression of the entire decision process. In contrast I will assume only that a decision is a progression of the decision taking process. A decision making progression is more comprehensive and it may involve steps not included in decision taking, such as the taking of a preliminary decision and the commenting and subsequent reworking and resubmission to the decision making pipeline of an improved preliminary decision outcome. A clear example of a decision making pipeline is presented in [30].

that is that a decision making progression is being produced. Instead of decision making process making I will simply speak of decision process making. Indeed in order to ensure that a decision making progression takes place many additional and supporting acts may be required which are nu subsumed under decision making because of the absence of impact on the decision outcome.

Decision process making may be compared with theater making, which is the making of a progression of acts or events of theater play (playing). Theater making is often performed by someone not actually playing him- or herself. This suggests that an external (second) agent might be involved in order to bring a decision about for some agent, comparable the role of a theater maker. One may think in terms of decision planning and control, with planner and controller different from the deciding agent. If the agent is a single individual this thought experiment coincides with the issue raised in [56]. A plausible term for that role is a decision consultant. The decision consultant, if present at all, sees to it that a decision takes place, or equivalently that decision taking takes place. Decision consulting and deciding operate simultaneously and interactively. The decision consultant is not involved in decision taking, because the consultant sees to it that another agent will take a decision. But as the consultant may be quite influential its actions may be included in the process of decision making.

2.6 An intrinsic circularity concerning decisions

If one intends to define the notion of an inhabitant of a country, one finds that for understanding a country as a social structure, one needs the notion of an inhabitant already. The notions of country and inhabitant must be defined simultaneously. A similar issue pops up when contemplating a definition of decision, or more specifically a decision taken by an agent (or a collective of agents) A. I will now argue that the concept of decision involves a circularity which I don't see how to remove. In fact in the definition of decision in Section 4 I will ignore this circularity, thus leaving open the question how to find an improved definition that takes it into account in a more serious way. The circularity comes from the fact that it is implausible to assign an agent the role of a decider without understanding what a decision is to begin with. Some agents simply cannot play that role. But in the definition in Section 4 I will not impose any constraints on the agent acting as a decider in an event to be considered a decision.

Indeed for A to be deciding it must be possible that A takes any decisions at all. The power to take decisions is constitutive for the concept of an agent for which it makes sense to assert that it takes any particular decision. A decision outcome x of a decision d taken by agent/unit A can be a plan, in which case it must be assumed that A has the power to see to it that the plan will be put into effect.[10] In other words a decision d can only be taken by an agent A if it has the

[10] According to [45] power can be understood as a medium comparable to money capable of ensuring that outcomes are put into effect. Power then constitutes a background mechanism within which an agent may be capable of taking some decisions and incapable of taking other decisions. Defining the power of an agent in terms of the decisions it may both take and be

power to take decisions from a class of (potential) decisions, say C_A containing d. After the outcome $o(d)$ has been put into effect, A's power to take decisions has potentially been changed, that is C_A may now differ (having become say C'_A) as a side effect of the implementation of the decisions outcomes. An obvious example of that state of affairs is found with an agent A who is deciding to buy some expensive real estate, and who, as a consequence of putting that decision into effect, is losing almost all of its cash and who is from that moment onwards in debt. $A's$ power to take decisions that will cost money (or rather, the putting into effect of the outcome of which will decrease the amount of money in A's disposal) has been significantly decreased.

3 Problem statement and solution outline

The problem to be analyzed and from some perspective solved in this paper is: what is a decision? In particular the answer given should be helpful to assess the following questions about decision processes in specific cases, in particular in a context of organizational decision processes.

3.1 Some questions and answers on decisions

These questions and answers should explain the choices made in the definition of decision that will be given in detail in Section 4.

- Given a specific theme or area, for relevance for some organization. What terminology is to be used about decision making concerning that theme?

  I will distinguish: decision process, decision, making, decision taking, and decision shaking. Give those notions: which agents are involved in the decision process, in decision making, in decision taking, and in decision shaking.

  Decision shaking is a political process performed by agents or groups of agents outside the hierarchical control of the decision taking agent, after and as a consequence of the decision having been taken. It leads to its destruction in hindsight as an authoritative statement. It renders the decision outcome futile. It may also have negative impact on the position of those who took the decision and even on those who were involved in the decision making process leading to the (shaken) decision.

- Suppose that an agent has concluded that he will probably be involved in decision making, or in decision taking concerning a topic: which activities are precisely involved in that role?

sure to see their outcomes being put into effect seems to be consistent with the analysis of [45].

A's power to make decisions can at each moment be defined as the collection of decision outcomes that (i) it may plausibly put into effect, and that (ii) are decision outcomes of decisions that it may take when operating according to the rules that have been set for the various types of decisions.

An answer to this question depends on circumstances which may vary from organization to organization and from theme to theme. Given an organization and a coherent (that is interrelated) bundle of themes of comparable importance for the organization, it is reasonable to assume that decisions can be classified into a number of classes, such that for each class taking a decision within that class requires that some protocol of preparatory actions (which may include some decisions) must be followed. Such a protocol is informative about the interface that an agent may use and make use of.

- How to refer to those activities involved in a decision process that are not part of decision making? Where are the boundaries with decision making and how to assess the relevance of these actions for the decision process?

  To answer these question an interface of basic actions (see [20]) must be determined which indicates the activities that can be performed by the chief decision taker. Some of these actions comprise the issuing of instructions to other agents who act in supporting roles.

- How to name key roles in the decision process? Here I will assume that human agents are at stake. If a group is taking decisions each of the members is said to be taking decisions.

  I will speak of a decision taking officer (DTO), given an organization and a bundle of themes of relevance for that organization, if an agent is regularly involved in decision taking about one of the themes in the bundle. A chief decision taking officer (CDTO) is always involved in the decision of highest importance. Both DTO en CDTO are supposed to have decision taking as their main activity within the organization.

  If a person is taking decisions only occasionally he is classified as DTP for decision taking personnel. Every (C)DTO is also DTP. Decisions taken by DTP in that capacity are either final decisions, that is decisions constituting the termination of a decision process, or preparatory decisions that are part of the protocol leading to a final decision.

  Besides DTP there is DMP, decision making personnel. Non DTP DMP is at least occasionally involved in preparatory steps for decision making. DMP personnel not classified as DTP need not be taking orders only. They may act at their own initiative to contribute to various phases of decision making, for instance by analyzing the expected effect of a proposed decision outcome, or by analyzing the risks posed by unintended side-effects of a decision, or by unintended consequences of a proposed decision outcome. Yet more comprehensive is DPP, decision process personnel. Non DMP DPP has a supportive role only and will not take any influence on decision outcomes.

- How can a dedicated decision taking agent be characterized in mechanical terms? In other words: what kind of procedures are put into practice

by an agent with a primary focus on decision taking (at some level of abstraction and in the context of some organization)?

The perspective of a (C)DTO is as follows: different decision processes take place as threads in a multi-threaded system. The (C)DTO is responsible for scheduling the multi-thread of decision processes by means of an appropriate form of strategic interleaving ([14]). In doing so the (C)DTO instructs other agents to take part in the decision process at large and in decision making fragments of it.

- What drives a decision process?

  A a decision process is a thread consisting of the putting into effect (see [9]) of a single pass instruction sequence α (see [11]) which itself is regularly extended by means of a background planning process. A (C)DTO is putting initial segments of α into effect while regularly extending it as an outcome of a planning process. The mechanics of the planning process are left unspecified.

3.2 Meta-decisions on the definition of decision

The proposed answer on the question what constitutes a decision as embodied in the definition in Section 4, involves some meta decisions with which one may disagree. Without taking the risk of such disagreement writing this paper is pointless. Here are the main meta decisions that enter my explanation of what is a decision:

- A decision is an action, taking place in space and time and it is the work of an agent who is responsible for the decision.

- A decision has an outcome, which is a representation of the content of the decision in a form which can endure in time. For a digital text posted on a website controlled by the responsible agent.

- The outcome must be distinguished from the effect of a decision, which is best seen as the consequences of implementing the outcome.[11] There may not be any effect if no agent bothers to implement the decision outcome. Producing the effect of a decision outcome by implementing it is not part of the decision process of that decision. The process leads up to the decision and ands at that stage.

- Decision taking differs from making a choice or expressing a preference, and decision making also differs form the determination of a preference.[12]

[11] In [61] one finds the convention that decision outcome stands for what I propose to call the effect of the decision outcome. If it has been decided to buy some gadget, the actual purchase is caused by that decision, and it may be considered the effect of the decision outcome.

[12] Nutt [43] considers choice a possible unit of analysis occurring as one of many actions to be considered when having a decision focus. He distinguishes between the unit of analysis and the level of analysis. Nutt also mentions the nesting of decisions as an aspect of scope regarding

Such tasks are often input to a decision but do not constitute the decision itself. As a consequence of this meta decision a major part of the literature on decision making has to be reclassified as being about making a choice or optimizing a possible selection from a menu of options. Thus: choosing is not deciding about a choice. Choosing is more primitive than deciding and less context sensitive. Deciding, however, may be based on a choice. If a choice lies on the path (pipeline. workflow) which creates a decision outcome in preparation of a decision d to be taken, that choice constitutes part of the decision making process (and hence of the decision process) for the decision d but not of the decision taking process a progression of which constitutes d.

- Decisions are always taken in a context where some awareness of intended effects (of the decision outcome) is present. Decisions are taken in order to bring expected effects of their outcome about.

- A decision d may itself be caused by one or more preparatory decisions which play a predefined role in a decision process. Taking the preparatory decisions is part of the decision making that culminates in the decision d being taken. Activities needed for the decisions involved in the decision making for d are part of its decision process.

- Even if a decision d produces an outcome with the subsequent and intended effect e, that effect may not have decision d as its most prominent cause. For instance it may be the case that some preparatory decision d_p has lead almost unavoidably to d being taken, in which case d_p is the cause of the effect e rather than d.

  Nevertheless the agent a who took decision d may subsequently be held responsible for the effect e (of implementing the decision outcome of d) even in the case that the "real cause" d_p has been a decision taken by another agent, say b. Perhaps b is held morally responsible for e in such a case.

- The term decidability as used in the theory of computation refers to the possibility to make some choice effectively. that is uniformly computed by means of an idealized computer. In the absence of any intended effects of that choice, an instantiation of decidability as an act of effectively making a choice between several options must not be considered a decision, but merely a choice. A consequence of this meta decision about the meaning of "undecidability" is that the so-called undecidability of the halting problem (see [17]) is not about the absence of the possibility to make some decision

decision making research. In [29] decision and choice are identified, though not explicitly. In [49] and [39] decision and choice are treated without distinction. In [26] a decision is essentially a choice but compiling the menu of options as well as developing predictions of the effects of various decision outcomes (that is options under the assumption that these have been chosen) is considered part of the decision as well. In [58] ethical decision making is understood as action selection under ethical constraints.

but about the absence of a method for effectively making a choice. So I would prefer the phrasing that the halting problem is not effectively solvable.

3.3 Alternative approaches to the same concept of a decision

An obvious difficulty with the above requirements stated about the notion of a decision is that whatever definition one comes up with, it will not fit in a few lines, thus defeating the extreme conciseness which characterizes concept definitions favored in the circles of management science. When asked to provide a shorter definition of a decision, which conveys some but perhaps not all of the content considered essential for a decision. Here are some options:

1. A decision is the promotion by an agent of some data representing a proposed decision outcome to the elevated status of a decision outcome.

2. An example of a decision is the act of giving (or refusing) permission to another agent to perform some activity, given a request by the other agent for that permission. The decision outcome is the statement (including motivation) of that permission (or refusal) in a durable form.

   Another example of a decision is to turn a preliminary decision into a final one after accommodating comments by various parties on the decision outcome of the preliminary decision. The decision outcome may for instance be the written intention to release funds for certain purposes, or the written intention to organize a specific meeting, or the written intention to terminate some operation, and so on.

   In principle the concept of a decision can be obtained as an inductively found generalization from a limited number of significant examples.

3. Decision taking (making) is the application (that is a meaningful instantiation) of a competence which one may prove to be in command of by having participated in a substantial range of decision taking (making) activities. Decision taking (making) competence is a community competence in the sense of [12].

   Two forms of openness can be distinguished: open expectation, open intention. I am inclined to rank open decisions of either or both kinds higher than closed ones. In addition an open intention decision can be deceptive which diminishes its quality.[13]

[13] Of course there are circumstances where the deception coming along with a decision is its key quality, but I will consider those circumstances exceptional and I will not insist that the mentioned quality criteria will apply as well in such exceptional cases.

4 Decision defined by way of construction

I will define a decision as an extended promise, that is the core of a decision is a promise as defined in [10], where a promise is taken to be a documented intention with an explicit scope of announcement.

A decision is an event (below referred to as The Event) which is specified in detail as a tuple containing the following items:

time and place Coordinates in space and time for The Event (with spatial coordinates being less important if the agent is an aggregate operating in a distributed fashion). The temporal information may provide a time interval rather than a single moment in time, because The Event need not be atomic in time.

timing The timing mechanism indicates how, or under which constraints, time (and place) of The Event are found. Concerning the timing mechanism several scenarios may exist such as for instance:

real time. The Event must take place at some specific moment in time. Its type and requirements are known in advance. Clearly human decision taking has an inherent imprecision in timing which cannot be overcome. Faster decision taking must be automated, which implies that some machine or software agent is considered to play the role of a decision maker.

fixed deadline. A decision (of some type, and satisfying some requirements of its outcome) must be taken before some known deadline.

opportunity interval. The decision may need to be taken within a given time interval, that is a temporal window of opportunity.

open end. There is no firm deadline for a decision but its type and more specific requirements are known.

go, no go. Like an open deadline decision but now the outcome requirements are fully specified. It may be that after some moment in time the outcome is vacuous, that is, the implementation of the decision outcome is an empty process if some moment in time has been passed.

decider The decider is an agent, including the option of an aggregate agent (that is a group of agents), in the role of a decision taker.

agent role A role in which the decider operates with regard to The Event. This attribute is essential if the agent is acting in different roles simultaneously at the specified time and place. An agent role can only be determined with some reference model of a social structure or an organizational framework in mind. This attribute must provide a true role, and not merely a name for it. From a role the power of an agent can be derived, at least in principle.

input data A package of data playing the role of decision inputs. These inputs typically include, a classification of the decision outcome to be produced, together with protocol information on how that kind of decision is to be made and taken, a menu of options, preferences imposed on the various menu items, test reports, artifact reviews and assessments, advice from external consultants, motivations for preferences, results of optimal choice analysis between menu items, proposed decision outcomes, historic data about the coming into existence of these proposals including data about who has been consulted on the basis of preparatory decision outcomes, which objections have been taken into account etc.

outcome A text, or more generally a meaningful symbolic or graphical code, in rigid or in spoken form, stored with some permanency, playing the role of a decision outcome.

outcome type A type or class to which the decision outcome is supposed to belong. The type information may also indicate which protocol must have been followed in preparation of the event. This is a non-exhaustive set of possible decision outcomes types:

reply. A Boolean reply concerning a question that has been put in advance.

assertion. An assertion of a fact, or of the endorsement of a fact. The fact may either be spelled out in the decision outcome or it may be known via a reference. Assertions may have further types such as: verdict, opinion, hypothesis, guess, claim, confirmation, and rejection.

plan. A plan to be put into action once triggered externally is a certain way.

promise body. For promise bodies see [24, 10].

command. A direction or command to be followed by other agents.

outcome novelty Given a decision outcome type additional constraints (or rather constraint types) on the outcome may exist, constraining the novelty of the outcome. Such constraints constitute part of the decision. Here are some possible values for this attribute.

closed solution. The decision outcome may be almost entirely known for some time already, and one waits for the corresponding decision to take place. (In this case the outcome represents no novelty at all.)

indication. A question together with a menu of alternative answers may be provided. The requirement is that the decision outcome indicates a choice of an answer. For each choice some numerical parameters may need to be instantiated in addition. (In this case the outcome represents no novelty at all, but the choice that has been made may be unexpected.)

half open solution. The menu of alternative answers as just mentioned may be merely an indication and other potential solutions may well exist. Then the decision will produce an outcome that may comprise the result of some creative activity. (This case implies limited novelty only.)

open solution. A problem area may be given together with the assertion that the decision (or rather the consequences of implementing its outcome) must contribute to its solution, though no indication of possible outcomes satisfying that requirement are given. (Novelty is possible.)

protocol The protocol indicates how the decision process leading to The Event must be shaped. At least the protocol indicates the start of the phase of indecision which has been brought to completion by The Event.

scopes There are several scopes involved in a decision:

endorsement scope. The endorsement scope contains those agents on behalf of whom The Event is performed. It contains at least the decider (who has been listed in a previous item). (Members of the endorsement group are alternatively called co-deciders or co-decision takers.)

primary announcement scope. Contains those agents to whom the decision outcome is addressed.

implementation scope. Contains those agents whose behavior will be guided (by those agents constituting the announcement scope) so as to put the outcome into effect.

secondary announcement scope. Those agents outside the primary announcement scope who will be told (or may be told) about the decision. This set may be empty in the case of a secret decision (also called a hidden decision). It is assumed that the decider sees to it that the decision outcome is not communicated outside the secondary announcement scope.

effect scope. Those agents whose existence is supposed to be influenced by the decision outcome being put into effect.

public expectation An expectation of the effects that announcement of the (decision) outcome will have. This information is made available within the announcement scope.

public intention An intention of the agent together with a motivation why the decision conforms to that intention. In particular it must be guaranteed that the decision taking agent has some grounds on which to base the expectation that the effect of announcing the decision outcome complies with the intentions. In an open intention decision the intention is documented and is communicated as a part of the decision outcome. In that case the decision

may be considered an enrichment of a promise. In a closed intention (or secretive intention) decision, the intention is not communicated in the way mentioned above.

An open intention decision may be deceptive if, viewed as a promise it is a deception (see [10] for that notion in the context of promises).

private expectation An expectation of the effects that announcement of the (decision) outcome will have. This information is made available only within the endorsement scope.

private intention A private intention is optional. If it exists it differs from the public intention.

risk analysis (Optional) a risk assessment that the decision outcome will fail to lead to the intended consequences. Risk assessment may split in a private and a public component.

4.1 Derived notions about decisions

Having a precise definition of decision available a variety of notions can be developed on top of it. These notions are useful when speaking of decision processes, decision making progressions, and decision taking progressions.

Implicit decision. An implicit decision (also named a postulated decision) is not a decision, at least not in general. In other words the decision to ϕ need not have existed even if ϕ is taking place and some observers may think of a decision to ϕ as a necessary precondition for doing ϕ.

However, if an organization functions in such a way that certain activities, say ϕ can only be performed when based on a preceding decision to that end, that decision may be referred to as the decision to ϕ, and such a decision may be termed an implicit decision

Primitive decision. A decision d is primitive if it is not a consequence of putting into effect a previous decision e for which the occurrence of d was an intended effect (that is such that the occurrence of d features amongst the intentions that constitute d).

Decision error. Various errors can occur when a decision is taken. For instance the co-deciders may not be sufficiently involved, an agent in the primary announcement scope may be missed out, agents outside the primary announcement scope may be informed. Further, the outcome may be phrased in meaningless language, it may be inconsistent with the public intention, time and place may not match the timing constraints, the agent may not play its stated role, the expectation (about the consequences of putting the outcome into effect) may be unjustified.

Decision management. Decision taking is performed by decision takers and co-decision takers, but it constitutes an activity which is mediated by other

agents and tasks. Decision management is performed by agents whose task it is to see to it that useful decisions are made properly. It is possible but not necessary that decision takers are decision managers as well.

Decision orchestration. Decision orchestration constitutes an aspect of decision management with a focus on the design of individual decision processes. Decision orchestration involves questions like: who must take a certain decision? What protocol must be involved when taking a certain kind of decision? Who should be involved in decision making, given a decision taking protocol.

Decision choreography. Decision choreography may also be considered a branch of decision management. Decision choreography takes place if a variety of decision processes is to be managed in parallel. Its focus in on the arrangement of interconnections between different decision processes that are progressing in parallel.

Decision taking competence. A community competence emerging from having played a variety of roles in a variety of decision taking processes (see [12] for a description of community competence).

Decision making competence. A community competence emerging from having played a variety of roles in a variety of decision making processes.

Decision ratification. In some cases a decision once taken needs some kind of public confirmation, for instance: crowning a king, handing over a certificate, publicly announcing an agent's bankruptcy. Ratification may be used for this, though in some cases ratification still may fail so that it is closer to decision taking after all.

The use of the terms orchestration and choreography has been borrowed from service science where these terms have been used with considerable success with a clear technical meaning from which the above proposals have been derived (see [46]).

4.2 Ramifications arising from the definition

The definition of decision given above gives rise to further questions. These questions may indicate the need for modifications and refinements of the definition.

Decisionness. In spite of the lengthy definition just given, it seems to be the case that an utterance of an agent being a decision is a gradual matter. There are no definite demarcation lines. Rather than defining when an event constitutes a decision, one may understand the above definition as an outline of a description of the concept of "degree of decisionality"

(that is the degree to which the event qualifies as a decision).[14] If all attributes are present the degree is very high (say equal to 1). If only an outcome exists and all other attributes are absent the degrees takes its lowest value, say 0. Different groups of stakeholders may disagree in their decisionality assessment of the same event. The mere statement that an utterance is referred to as a decision by the agent making the utterance does not in itself contribute to the degree of decisionality, though many agents will be happy to label their own utterances as decisions, in spite of defects concerning one or more of the criteria mentioned in the definition of decision above.

Definition complexity. The above definition of decision is both lengthy and complex. Can it be the case that an important notion like decision is in need of a definition of this complexity? Or is the entire project of defining decision heading in the wrong direction if it leads to a result that is hard to memorize in the first place. For the moment I think that a definition of this complexity may be needed to find firm ground for a theory of decision taking. More concise definitions can be developed subsequently for application in a specific context.

Decision templates. When it is said that some decision must be taken, this means that partial information about a decision is given in advance (called a decision template), which may or may not include the identity of an agent, that it is expected of some agent (or in case it is contained in the decision template, the agent mentioned in the template) that it produces a decision the the description of which completes the given decision template. Many different decision templates are conceivable, and much less information than required by the above definition may be included in a template. The concept of a decision seems to have been simplified by the simplicity of its most common templates. Notwithstanding that, a decision when taken brings together all information as mentioned in the above definition.

Nested scopes. A decision can be unexpected for agents in its scope. To understand this it must be assumed that scopes are collections of agents, and that various scopes, ordered by inclusion come into play when defining a decision.

For instance, the phenomenon of an episode of indecision will be noticed by agents in some scope between the endorsement scope (decision taker scope, or decider scope) and the primary announcement scope. The scope

[14] In [9] I have introduced the notion of a degree of executionality in order to deal with the problem that I could not find any convincing and straightforward definition of the notion of instruction sequence execution (a progression of machine steps constituting an execution of an instruction sequence, with instruction sequences defined as in [11]). In [13] the degree of outsoucingness was coined in order to deal with gradual phenomena that occur if one plans to define under which circumstances a sourcement transformation qualifies as an outsourcing.

of decision making agents (decision maker scope) extends the endorsement scope, but it need not be included in the primary announcement scope.

Label justification. Is every event which is called (labeled) a decision in fact a decision. This is a matter of justification. And conversely: are all decisions (that is activities or progressions that comply with the above definition of decision) indeed marked as decisions. The state of affairs seems to be as follows. Labeling a progression a decision may be unjustified. But agent A may still have an interest in doing so. A decision need not be labeled (called, referred to) as a decision. But some actions may be elevated to the status of a decision by being referred to in that way.

If in a religious ceremony the minister or priest declares a couple married, that act qualifies as a decision according to the given definition, although will not often be labeled as such. The couple has made a preliminary decision, the effect of which has been amongst other effects that the dignitary has planned the ceremony and has prepared the certificate that serves as a decision outcome. What makes one reluctant to label the minister's or priest's action as a decision is the lack of choice. The dignitary, however, might have declined to marry the couple for a variety of reasons. In general such reasons would surface prior to the ceremony but that sort of thing happen with many other types of action that are commonly labeled as decisions just as well.

Causal chains of decision. Given an organization, some activities performed by individuals or groups of its members require that some preparatory decision has been taken so that the activity can be understood as a consequence of the decision.

Non-decision actions. Most actions that occur in a business process are not part of a decision process. This matter has been discussed in Paragraph 2.3.2. Once a focus on decisions is introduced and a decision is said to be an action (which may or may not be atomic in time and space), the term action is not by default referring tot a non-decision. Lacking a positive qualification for an action not being a decision I borrow the phrase target action from [14] for non-decision process actions. The idea is that decision making is performed within a system in order to allow it to properly perform its main task consisting of a multitude of target actions. For instance the decision to schedule a course leads to the many target actions involved in delivering the course.

The notion of a target action is relative to a class of decisions. Seen from a higher level of abstraction, that is from the standpoint of decision choreography the decisions occurring in a progression of one of the participating decision processes are mere target actions. However, at the level of a particular decision process resulting from decision orchestration, the same progression may be viewed as an alternation of decisions, decision making actions, decision process actions, and target actions. These target

actions may in turn be decomposed in an choreography controlled parallel composition of orchestrations each of which may constitute an alternation of target actions (at some lower level), decision making actions and decisions.

Can animals take decisions? The definition given above leads to the proposition that animals cannot take decisions, mainly because they cannot produce "results". Here a result consists of storable and meaningful information. Of course most animals can make choices, but that is a different matter. Still this assertion is a matter worth more attention, it might be mistaken on biological grounds, or it might be considered unfortunate to the extent that it constitutes an incentive to rework the definition of decision.

Once this view is adopted it becomes implausible that a solitary operating human being without support of some form of technology, including social and organizational technology, can take decisions.

5 Decision taking theory

The extensive definition of decision may prove its value by constituting a productive point of departure for developing a theory of decision. The definition itself must be considered a part of a theory of decision, to some extent it already qualifies as a theory of decision, irrespective of the merits of that theory.

Decision theory is a classical phrase. In [53] and in [36] it is identified with the theory of making a choice between a variety of possible actions. It is possible to leave that meaning unchallenged if one admits or accepts that decision theory is not about decision taking but about choice making (that is choosing). For this reason I will speak of decision taking theory if the theory is about decision taking with decision defined as in Section 4. Of course decision taking theory has many variations parametrized by different definition of decision and decision taking. Nevertheless I require of decision taking theory that it is based on a concept of decision which is takes a choice as an input rather than incorporating the choice as its essence.

5.1 Leadership without decision mechanism: decision free management

The language of decision making has become so ubiquitous that it seems obvious that organizations must have leadership for taking decisions. This is clearly not true, however, because an organization can for instance be managed by agents who issue commands which are not resulting from any known or specified, let alone monitored, decision process. It is also possible to manage an organization by having informal rules in place which to some extent allow subordinates to find out what they should do or say in order to please their leadership. In that scenario the leadership may confine itself to issuing rather vague and abstract

declarations only, nowadays often called mission statements, which are subsequently interpreted by functionaries working at a lower level in the organization.

Decision free management is an effective form of management for relatively small organizations.[15]

Decision free management may operate in many different flavors and styles, and may adapt itself statically or even dynamically to different circumstances. The two extreme forms are a top-down line of command and a loosely coordinated collective of functional agents striving towards a common abstract goal. Each decision free management style can be modified, and sometimes improved, by introducing some forms of decision taking.

5.2 Implementing a decision mechanism

For a decision to occur or to be taken by some specific agent or by some group of agents certain preconditions have to be met. Getting these preconditions arranged amounts to implementing the very concept of a decision itself.

Thus implementing decisions takes place at a different level of abstraction from the implementation (putting into effect) of specific decision outcomes. In order to highlight that difference I propose to speak of "implementing a decision mechanism" rather than of the equivalent "implementing decisions". Boards, management teams, councils, congresses, and so on each provide such arrangements in different ways. I understand the ubiquitous presence of management teams and boards of directors as an indication that a decision making structure has been put in place. Without any such structure decisions cannot be taken, though perhaps equivalent actions (in terms of their consequences) can be performed.

Why are organizations implementing decisions, in their different ways? The need for decision taking arises from different arguments. Here is a brief and non-exhaustive survey of such arguments.

Transparency. By having important actions arranged as the effect of decisions the how and why of management activity becomes simpler to grasp for external observers.

Fraud prevention. Properly logged decision processes allow external observers and auditors to monitor the behavior of an organization, and to guarantee that only permissible arguments are used for making choices and for creating decisions.

Responsibility sharing. Very consequential actions can be based on the outcome of group decision processes, with the benefit that individual participants

[15] In The Netherlands, from some size onwards, an organization needs to maintain a works council operating according to a Dutch law, the WOR (wet op de ondernemingsraden). In an organization that uses decision free management in the absence of a works council, the introduction of a works council may necessitate putting well-defined decision making protocols in place at various levels of the organization. A works council interacts with management in terms of a discourse about decisions, decision making and decision outcomes.

of the decision process need not carry the full weight of the responsibility for the actions.

Speed control. Only by having a well-organized and well-monitored decision process in place an organization can improve its responsiveness for a variety of external requests and events.

Preventing tunnel vision. Small groups of individuals who are operating or managing in a sustained flow of activity run the risk of getting caught in a so-called tunnel vision: one one way ahead can be imagined. Whereas that is true in an ordinary tunnel, it seldom applies to a more open problem area. A well-organized decision process may prevent the occurrence of leadership tunnel vision.

5.3 Decision quality

A most plausible application of decision taking theory is that it leads to agent abilities, or conjectural abilities following [12], which enable the agent to improve the quality of decisions to which it contributes by participating in the decision taking process, or in the decision making process or in the decision process. Defining decision quality emerges as a major objective in decision theory development.[16]

A decision is of a higher quality (compared to another decision) if one or more of the following criteria hold:

1. The effect of the decision outcome is more likely to correspond to the decision taking agent's intention. In other words the decision outcome is more realistic. Unavoidably the operational context in which an agent is active comes into play. By managing that context in such a way that decision outcomes are more likely to have the intended impact the quality of decisions improves, even if outcomes are formally identical. Indeed quality assessment of decisions involves effects as well as outcomes.

2. The assumptions on which the motivation for a decision outcome is based have been better validated.

3. The expected difference in terms of consequences between taking the decision and not taking any decision at all (about the same theme in the same context etc.) is higher.

4. The decision turns out to be (more) final rather than that it is to be classified as (more) paving the way towards a subsequent decision[17]

[16] In [55] decision quality is distinguished from decision success, indeed quality measures the likelihood of success rather than the success itself. In [5] decision quality is identified with decision process quality, at the exclusion of decision outcome quality. However, decision outcome in [5] corresponds to decision (outcome) effect in the current paper.

[17] This criterion includes a better robustness of the decision outcome against complaints and legal objections, in other words, subsequent decision shaking is not plausible.

5. The decision is closer to the most impacting decision that might have been taken at the same moment of time by the same agent concerning the same theme, with the same intentions in mind.[18]

6. The progression of the decision process that has led to the decision is more in accordance with the protocol that must be followed for the particular kind of decision at hand.

7. The decision process leading to the decision has made better use of available resources.

In [1] one finds the observation that there is a paradox hidden in the quest for decision quality: if a decision process maker plans to involve different specialists in the decision making process, the risk of disagreement increases. In particular if the specialists are invited to think out of the box such disagreements may flourish. That in turn may lead to conflict which subsequently decreases the likelihood that decision outcomes induces the expected effects. From [1] one may conclude that only if affective disagreement amongst staff members can be avoided, decision quality profits from inviting staff to disagree on the substance of choices that have to be made.

5.4 Decision making models

Literature abounds with models of decision making processes. Different models may best fit different circumstances. A survey of models is given in [54] where it is also claimed that model selection cannot be performed on the basis of generally agreed rational arguments, rather it is a matter of contingency. A classic model is the garbage can model of [25]. The garbage can model incorporates an architecture of a problem solving model into a model of a decision making life-cycle.

The definition of decision taking presented above has no bias towards any specific decision making model. To begin with the definition leaves open many degrees of freedom for a definition of decision making. More importantly the models exist at a higher level of abstraction where the rationale of different steps constituting a decision making progression is qualified.

Besides decision making models there are organizational paradigms in which decision making can play a more or less pronounced role. In [35] a paradigm of organizational design is presented which centers around getting adequate decision processes in place. The definition of decision taking is supposed to be independent of organizational paradigms, though it must be sufficiently flexible to deal with the various decision making workflows that a particular organizational paradigm might prescribe.

[18] It seems to be impossible to decouple the quality assessment of a decision from the intentions of the deciding agent. If those intentions are unknown no quality assessment is possible.

5.5 Levels of decision making and taking

An agent a which is involved in decision taking is confronted with the question how many of its actions are decisions. If one drives by car to the state agent in order to take a decision about the acquisition of some real estate, then one may be tempted to reserve the phrases decision taking, decision making, and decision process only to decision regarding real estate ownership, or with an equal level of importance. Other activities like the car driving through dense traffic or the preceding selection of a means of transportation take place at a somewhat lower or at least different if not disjoint level of importance. These other activities may involve decision taking as well. In the extreme every action performed by the agent may be considered the consequence of the outcome of some implicit or explicit decision. When, however, a level of abstraction and a theme t has been chosen it becomes possible to distinguish between agent a's actions that are connected with decisions concerning t and other actions, which then are not said to be part of the decision process, even when seen from the perspective of another theme some of those actions are also to be classified as decisions.

In a modular organization decisions are taken and made in different organizational modules concurrently. Encapsulation and abstraction are needed to analyze to what extent decision taking activity and decision making progressions occurring within a certain module can be influenced and observed from different modules. Encapsulation and abstraction are notions which have been given a quite precise meaning in process algebra (see [3]) and it will be a matter of future work to develop these notions with a special focus on decision taking and decision making.

5.6 Hierarchy of themes

Both for an agent and for an organization comprising many agents different themes may be distinguished about which decision can occur. The simplest picture is a hierarchy of importance, where decision processes of a higher importance take place interleaved with process fragments in which decisions of lower importance are taken. Unfortunately this hierarchy is a difficult matter because so-called low level tasks may involve "go-no go" decisions to be taken which are safety-critical, e.g. whether or not to make an outing in the mountains on a given day or whether or not to make use of a car with a known technical problem, whether or not to be transported by a driver who one does not really trust, and so on.

The better picture may be that at the top level of the hierarchy there are tactical decisions which are potentially safety-critical though lacking any strategic importance. Below those there may be several independent layers of decision processes for various themes of strategic importance, such as stock market investment, real estate maintenance, job rotation, and family planning. Below that is a vast number of processes involving necessary decisions which lack strategic importance as well as any substantial risks, such as holiday timing,

choosing a restaurant, buying furniture, and the fulfillment of social obligations. Below that there are processes which involve numerous choices that don't qualify as decisions such as when to do shopping, when to walk the dog, whether or not to halt for some specific traffic light, when to stop filling one's cup of coffee, when to do some house keeping, where to buy a bottle of wine, which telecom provider to use, when to reload one's mobile phone and so on.

5.7 Hierarchical decision structure inside an organization

Assuming for the sake of simplicity that the management structure of some organization is like a tree rather than the more usual matrix, where most nodes are individual agents and some nodes consist of groups of agents, that is executives, managers, or disciplinary oriented employees. A hierarchy in the form of a downwards hanging tree is probably too simple a model given the matrix organization that many organizations prefer, but it helps to visualize the complexity of decision taking and making. I will assume that each agent occupies a single node in the tree only, in some cases operating as a member of a group of agents. One may rank individuals according to their distance to the top of the tree. The board operates at level 0 and so on. Halfway the tree one finds the so-called middle management. Their role is the most complex. The picture given will be simplified in comparison to a real case but it helps form an intuition.

Consider an agent a at level $k > 2$. At the level of a some types of decisions are taken, perhaps with the help of agents of at least the same rank. Typically a may be putting into effect a number of threads, by way of multi-threading with a suitable strategic interleaving, one for each of the decisions to which a has a commitment to bring it about by managing its preparation and then enacting it to be taken. For a single prospective decision d, say of type D, agent a can make use of an interface of actions I_D, such actions may involve: planning a meeting, asking a colleague for comment, writing a proposed decision outcome for d, writing a preparatory proposed decision outcome for d, issuing a staff member acting at level $k + 1$ or higher to perform one of these tasks, holding a meeting, asking others to review a text and so on.

This leads to a processing a multi-thread for handling a plurality of decision taking tasks. A the same time, however, a may be carrying out actions that may classify as decision making (though not taking) for decisions to be taken at level $k - 1$, this again leading to a multi-thread of tasks for decisions which will be taken by a's immediate superiors (having rank below k by definition). In addition a may be dealing with a multi-thread for tasks that play a role in the decision process for decisions which are going to be taken at level $k - 2$.

Working at level k it is feasible for a, in principle to produce preparatory work which may serve as an incentive for staff at levels below k to generate objectives that may involve some decision taking. In some cases a can be more influential by proposing ideas for decisions to be taken at higher levels than by deciding about issues that have been determined as belonging to level k or higher.

Looking down in the power structure at each level decisions are taken for

which a carries some responsibility. Sometimes such decisions are taken in response of questions emanating from a or from staff members or staff groups with higher authority (that is having lower rank). In other cases these decisions are taken without having been given a trigger from above in advance. That takes place when a predefined workflow is put into effect and if that workflow calls for a decision to be made.

The combination of these multithreads for each deciding agent is again put in parallel by means of a strategic interleaving operator. This kind of composition has been analyzed in detail in [15].

5.8 Conjectural abilities implied by the proposed theory of decision taking

Following [12] awareness of an agent a of a theory of X may lead supporters of that theory (amongst which its author(s)) to attribute conjectural abilities concerning X to a.

The definition of the notion of decision and its surrounding notions can be considered a theory of decision. Whatever its academic merits, awareness of this theory may constitute an addition to an agents competence profile by way of the acquisition of additional conjectural abilities. Theories of decision from management science often focus on top level decision taking and supporting processes. At top level, however, the question to what extent one is involved in decision taking or making is often not felt as problematic.

Lower ranking staff members may have more difficulty in assessing their place in an organization's control system. For middle management the analysis of decision may have some attraction, because it may be helpful for assessingg one's contribution. Taking the agent a at management level $k > 2$ from the top as an example the following conjectural abilities come to mind:

1. Being able to organize one's participation in range of different decision processes, by classifying this participation as being merely to the decision process, to decision making, to decision taking, or finally to decision shaking, and by viewing these participations as threads in a hierarchical multi-thread under control of a by means of strategic interleaving. (See [14, 15].)

2. Being aware of the variety of protocols that govern decision processes, as well as of the meta decision processes that determine these protocols.

3. Being inclined to assess and to forecast and in some cases to influence the quality of decisions made by agents at different levels.

4. Being able to balance the participation to each of these threads in such a way that influence is maximized.

5. Being aware that each participation to a decision process may be influential, in particular roles that are classified as decision making but not as

decision taking, and decision process roles that don't qualify as decision making roles.

6. Being aware that a's participation, by being embedded with the full range of decision processes, may well be intrinsically more complex than the participation of staff positioned at levels 0 and 1, the so-called top-management.

7. Being aware that the quality of decision taking cannot be decoupled from the planning of decision taking. The ability to forecast that a certain kind of decision will turn out to be effective is an essential decision process design capability. This ability need not be confined to so-called top management. That foresight may also appear as a decision making capability or as a decision process making capability. Indeed, staff members at lower levels of the hierarchy may well consciously trigger chains of events from which decisions that will eventually be taken by higher management will emerge, even if they don't participate in either decision making or decision taking, for that particular kind of decision.

8. Understanding in mechanical terms why a middle manager with a clear sense of direction need not be less influential than a top manager without a clear sense of direction. At the same time, given the non-empty sense of direction aggregated at middle management level, it appears why top management can often do with much less sense of direction than one might expect. They only need to reinforce what pops up in terms of options for decision making and decision taking.

9. Awareness of the fact that a decision it itself an activity which may be in need of algorithmic control. An important part of preparatory work may consist of the development of an instruction sequence, perhaps equipped with conditions phrased in a short-circuit logic, or more generally a proposition algebra (see [21]), which needs to be put into effect in real time in order to compute the decision outcome that must to be produced. The act of deciding, that is the decision (what else can it be), then reduces to the decision to put an instruction sequence into effect.[19]

6 Concluding remarks

The first conclusion consists of a brief survey of informatics perspectives on decision taking which takes the results of the paper into account.

[19] At this point the concepts unfortunately become less clear. If an instruction sequence has been determined in advance (as a part of decision making, or even merely as a part of the preceding decision process) in order to compute the decision outcome when a decision, of a particular kind, is taken, then one must distinguish two cases: (a) the instruction sequence is put in to effect by "manual operation" by the decision taking agent, in which case the resulting progression can be termed a decision without hesitation, provided it comes to an end, and (b) the instruction sequence is put into effect by automatic means outside the agent's immediate control, in which case one may prefer to refer to the act of putting into effect as an implicit decision, or even as no decision at all.

6.1 Informatics perspectives on decision making

I will use decision making as a reference to the bundle: decision process making, decision making, decision taking, decision shaking. Which perspectives from informatics can be formulated.

- Description methods for: (decision outcome) typing, (decision process) protocols, modeling in time of decision processes.
- Protocol support for decision processes, for instance by way of providing workflow models and assistance.
- A mechanical perspective consisting of a multi-thread with strategic interleaving view on DTO and CDTO activity.
- Informatics based terminology for running processes: progression, trace of a thread, concurrent operation, run of a machine, putting an instruction sequence into effect, precondition, postcondition.
- Formulating real time aspects of decision taking in terms of preparatory design of instruction sequences making use of conditions phrased in short-circuit logic.
- Decision support systems: in practice many decision support systems mainly provide choice support, but all automated support for the decision process design and decision process control count as decision support.

6.2 Decision taking as an informatics competence

Under the assumption that a decision outcome is a piece of information decision taking is technically equivalent to the promotion of the preliminary decision outcome to a definite status, assuming in addition that the features required by the definition of decision are present indeed. It all has to do with information status, information classification, communication, information visibility, adherence to protocols, information processing workflow, and it is embedded in a multi-threaded setting. Assuming in addition that choice, however sophisticated in a practical case, plays a supportive role only, decision taking becomes an information processing competence. Writing informatics for information processing it follows that decision taking is an informatics competence.

6.3 Decision versus promise

A remarkable outstanding issue is to clarify the relation between decision and promise. Some promises are decisions and some decisions are promises. According to many authors (e.g. [2], [50]), though not according to Burgess in [23, 24] and several other works, a promise effects some obligation. In general a decision seems not to have the creation of an obligation as an effect. The deciders power stands in the way of its becoming obliged by its own activity.

Following Burgess' line of thinking a promise of action is a decision taken by an agent about its own future activity. As a decision it is not binding. Promises may concern other aspects than an agent's activity, such as a current or future state of affairs. As it stands decisions have that flexibility as well. I guess that, assuming Burgess' constraint on promises that they don't imply any obligation, each decision is also a promise. Some decisions, however, may not respect other agent's autonomy to the extent that Burgess claims mandatory for promises if they are to play a role in systems design and analysis. Thus following Burgess' position on promises the class of decisions which cause no infringement on the autonomy of any agents different from the decision's decider is of special importance. precisely those decisions are enrichments of the promises which Burgess acknowledges as playing a role in system specification and design.

6.4 Further work

This paper is less than clear about the classification of actions some of which qualify as decisions. In order to develop a comprehensive theory of decision making a classification of actions that do not qualify as decisions is essential. If one understands an organization as a tree-like network of units, each running decision processes that may influence the future of other units the question appears how decisions look from a distance. From a sufficiently large distance the fact that decision taking occurs may be invisible. It is encapsulated so that from a distance decisions cannot be influenced and its residual actions are abstracted away so that the very occurrence of decision processes has become invisible. A myriad of abstractions in between exists in practice, however. A clear language for speaking about such matters must yet be developed.

Another issue is that looking down in terms of the hierarchy to a decision process differs from looking up to it. Decision processes by higher management layers seem to make more sense to lower layers in a hierarchy than the other way around. Higher management levels may be inclined to view decision processes at lower levels as redundant and standing in the way of the real work. Viewing upwards it is often the case that decisions are considered to be either mistaken or delayed.

These matters can only be considered in detail once appropriate forms of encapsulation, for restricting remote influence on decision processes, and abstraction for restricting the options for obtaining information about remote decision processes, have been developed with some sophistication. I expect that the language of process algebra (see [3]), in which encapsulation and abstraction pay a central role, will be helpful for developing an approach to this matter.

References

[1] A.C. Amason. Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: resolving a paradox for top man-

agement teams. *The Academy of Management Journal.* Vol. 39 (1) pp. 123–148, (1996).

[2] P.S. Atiyah. Promises, morals and law. *Clarendon Press, Oxford.* (2003).

[3] J.C.M. Baeten, T. Basten and M.A. Reniers. Process Algebra: Equational Theories of Communicating Processes. *Cambridge Tracts in Theoretical Computer Science.* Vol. 50, (2009).

[4] H.T. Barney, G.C. Low, and A. Aurum. The morning after: what happens when outsourcing relationships end? *In: G.A. Papadopoulos et. al. eds. Information Systems Development, Springer LLC,* pp. 637–644 (2009)

[5] C. Bayley and S. French. Designing a participatory process for stakeholder involvement in a societal decision? *Group Decision and Negotiation* Vol. 17 pp. 195–210 (2007)

[6] J.A. Bergstra. Formaleuros, formalcoins and virtual monies. `arXiv:1008.0616 [cs.CY]`, (2010).

[7] J.A. Bergstra. Informal Control Code Logic. `arXiv:1009. 2902 [cs.PL]`, (2010).

[8] J.A. Bergstra. Real Islamic Logic. `arXiv:1103.4515 [cs.LO]`, (2011).

[9] J.A. Bergstra. Putting Instruction Sequences into Effect. `arXiv:1110.1866 [cs.PL]`, (2011).

[10] J.A. Bergstra and M. Burgess. A static theory of promises. `arXiv:0810.3294 [cs.MA]`, (2008).

[11] J.A. Bergstra and M.E. Loots. Program algebra for sequential code. *Journal of Logic and Algebraic Programming*, 51 (2), pp.125–156, (2002).

[12] J.A. Bergstra, G.P.A.J. Delen, and S.F.M. van Vlijmen. Outsourcing Competence. `arXiv:1109.6536 [cs.OH]`, (2011).

[13] J.A. Bergstra, G.P.A.J. Delen, and S.F.M. van Vlijmen. Stratified Outsourcing Theory. `arXiv:1110.1957 [cs.SE]`, (2011).

[14] J.A. Bergstra and C.A. Middelburg. Thread algebra for strategic interleaving. *Formal Aspects of Computing*, 19 (4) pp. 445–474, (2007).

[15] J.A. Bergstra and C.A. Middelburg. Thread algebra with multi-level strategies. *Fundamenta Informaticae* 71(2/3), pp. 153–182 (2006).

[16] J.A. Bergstra and C.A. Middelburg. Machine structure oriented control code logic. *Acta Informatica*, 46 (5) pp. 375–401, (2009).

[17] J.A. Bergstra and C.A. Middelburg. Autosolvability of halting problem instances for instruction sequences. (`arXiv:0911.0518 [cs.LO]`), (2009).

[18] J.A. Bergstra and C.A. Middelburg. Partial Komori fields and imperative Komori fields. (`arXiv:0909.5271 [cs.LO]`), (2009).

[19] J.A. Bergstra and A. Ponse. Execution architectures for program algebra. *Journal of Applied Logic,* 5 (1) pp. 170–192, (2007).

[20] J.A. Bergstra and A. Ponse. A progression ring for interfaces of instruction sequences, threads and services. `arXiv:0909.2839 [cs.PL]`, (2009).

[21] J.A. Bergstra and A. Ponse. Proposition Algebra. *ACM Transactions on Computational Logic*, Vol. 12 (3) Article 31 (36 pages), (2011).

[22] M. Bommer, C. Gratto, J. Gravander, and M. Tuttle. A Behavioral Model of Ethical and Unethical Decision Making. *Journal of Business Ethics*, Vol. 6 pp. 265–280 (1987).

[23] M. Burgess. An approach to understanding policy based on autonomy and voluntary cooperation. in: *Ambient Networks, Springer LNCS,* Vol 3775 pp. 97–108, (2005).

[24] M. Burgess. System administration and the scientific method. in: J.A. Bergstra and M. Burgess (editors), *Handbook of Network and System Administration,* pp. 689–728, (2007).

[25] D.K. Cohen, J.G. March, and J.P. Olsen. A garbage can model of organizational choice. *Administrative Science Quarterly* Vol. 17 pp. 1–25, (1972).

[26] R.M. Cyert, H.A. Simon, and D.B. Trow. Observation of a business decision. *The Journal of Business,* Vol. 29 (4) pp. 237–248, (1956).

[27] G.P.A.J. Delen. Decision and Control Factors for IT-sourcing. in: J. A. Bergstra and M. Burgess (editors), *Handbook of Network and System administration*: pp. 929–946, (2007).

[28] J.W. Dyckman Planning and decision theory. *Journal of the American planning Association*, Vol. 27 (4) pp. 335–345 (2010).

[29] A. Etzioni. Normative-affective factors: toward a new decision making model. *Journal of Economic Psychology*, Vol. 9 pp. 125–150 (1988).

[30] V.H. Fried and R.D. Hirsch. Toward a model of venture capital investment decision making. *Financial Management*, Vol. 23 (3) pp. 28–37 (1994).

[31] M.B. Folsom. Executive Decision Making. *McGraw Hill, New York*, (1962).

[32] J. Hage. Theories of Organizations: Form, Process and Transformation. *Willey, New York*, (1994).

[33] H.A. Heatfield and J. Wyatt. Philosophies for the design and development of clinical decision-support systems. *Methods of Information in Medicine*, Vol 32, pp 1–8 (1993).

[34] D.J. Hickson. Decision-Making at the Top of Organizations. *Annual review of sociology,* Vol. 13, pp. 165–192, (1987)

[35] G.P. Huber and R.R. McDaniel. The decision-making paradigm of organizational design. *Management Science*, Vol. 32 (5), pp. 572–589, (1994).

[36] R.C. Jeffrey. Valuation and acceptance of scientific hypotheses. *Philosophy of Science*, Vol. 22 (3) pp. 247–249, (1956).

[37] R.L. Keeney. Creativity in Decision Making with Value-Focused Thinking. *Sloan Management Review*, summer 1994, pp. 33–41, (1994).

[38] K. Kimbler and L.G. Bouma (Eds.) Feature interactions in telecommunications and software systems V. IOS Press, (1998).

[39] D. Mahalel, D. Zaidel, and T. Klein. Driver's decision process on termination of the green light. `Accident Analysis and Prevention`, Vol. 17 (5) pp. 373–380 (1985).

[40] J.E. McConnell. The export decision: an empirical study of firm behavior. *Economic Geography*, Vol. 55 (3) pp 471–183 (1998).

[41] C.A. Middelburg. Searching publications on software testing. `arXiv:1008.2647 [cs.SE]`, (2010).

[42] B.A. Mellers, A. Schwartz and A.D.J Cooke. Judgement and decision making. *Annual Review of Psychology*, Vol. 49 pp 447–477 (1998).

[43] P.C. Nutt. Making decision-making research matter: some issues and remedies. *Management Research Review*, Vol. 34 (1) pp. 5–15 (2011).

[44] M.J. O'Fallon and K.D. Butterfield. A review of the empirical ethical decision-making literature. *Journal of Business Ethics*, Vol. 59, pp. 375–413 (2005).

[45] T. Parsons. On the concept of political power. *Proceedings of the American Philosophical Society*, Vol. 107 (3) pp. 232–262 (1963).

[46] C. Peltz. Web services orchestration and choreography. *Computer*, Vol. 36 (10) pp. 286–295 (2009).

[47] R.C. Pinto. Argumentation and the force of reasons. *Informal Logic*, Vol. 29 (3) pp. 46–52 (2003).

[48] D.A. Rosati. Developing a systematic decision-making framework: bureaucratic politics in perspective. *World Politics*, Vol. 33 (2) pp. 234–252 (1981).

[49] T.L. Saaty. Decision making with the analytic hierarchy process. *Int. Journal of Services Sciences*, Vol. 1 (1) pp. 83–98 (2008).

[50] H. Sheinman. Introduction: promises and agreements. *in Ed. H. Sheinman, Promises and Agreements, Oxford University Press.* pp. 3–57 (2011).

[51] D. Simon. A third view of the black box: cognitive coherence in legal decision making. *The University of Chicago Law Review*, Vol. 71 (2) pp. 511–586 (2004)

[52] H.A. Simon. Administrative decision making. *Public Administration Review*, Vol. 25. (1) pp. 31–37 (1965)

[53] P. Suppes. The philosophical relevance of decision theory. *The Journal of Philosophy*, Vol. 58. (21) pp. 605–614 (1961)

[54] C.J. Tarter and W.K. Hoy. Toward a contingency theory of decision making. *Journal of Educational Administration*, Vol. 36 (3) pp. 212–228 (1998).

[55] S.G. Trull. Some factors involved in determining total decision success. *Management Science*, Vol. 12 (6) pp. 270–280 (1966).

[56] M. Valdman. Outsourcing Self-Government. *Ethics*, Vol. 120. (4) pp. 761–790 (2010)

[57] D. Vickers. Time, ignorance, surprise and economic decisions: a comment on Williams and Findlay's "Risk and the role of failed expectations in an uncertain world". *Journal of Post Keynesian Economics*, Vol. 9. (1) pp. 48–57 (1986)

[58] W. Wallach, S. Franklin, and C. Allen. A conceptual and computational model of moral decision making in human and artificial agents. *Topics in Cognitive Science*, Vol. 2, pp.454–485 (2010).

[59] B.N. Waller. Classifying and Analyzing Analogies. *Informal Logic*, Vol. 21 (3), pp.199–218 (2001).

[60] D. Walton and F. Macagno. Defeasible classifications and inferences from definitions. *Informal Logic*, Vol. 30 (1) pp. 34–61 (2010).

[61] R.A. Westbrook, J.W. Newman, and J.R. Taylor. Satsifaction/dissatisfaction in the purchase decision process. *Journal of Marketing*, October 1978, pp. 54–66 (1978).