Goal-Setting and the Logic of Transport Policy Decisions

Holger Rosencrantz

STOCKHOLM, 2009
This doctoral thesis consists of the following papers preceded by an introduction:

I. Rosencrantz, H. “Combining policy goals and welfare economics: the case of Swedish transport,” Submitted manuscript.


III. Grüne-Yanoff, T., and H. Rosencrantz “Beneficial risk increases,” Submitted manuscript.


V. Rosencrantz, H. “Deontic paradoxes: sources and solution,” Submitted manuscript.

Paper II is reprinted with permission from Elsevier. Paper IV is reprinted with permission from Springer. Rosencrantz was the main contributor to the transport-specific sections of Paper II, while Edvardsson and Hansson contributed equally to the theoretic sections. Rosencrantz was the main contributor to the appendices as well as to the graphics of Paper III, while Grüne-Yanoff was the main contributor to the non-formal discussion and literature review. Permission to reprint the papers in this volume is granted by all authors of each paper.

The introduction is partly based on the following paper:


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to Hampus and Lucas, my nephews
Abstract

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The thesis aims at developing approaches to transport policy decisions, based on suggestions 
and ideas originating from moral philosophy and philosophical decision theory.

Paper I analyzes the Swedish transport policy goals, and the problem of combining policy 
goals with welfare economics. A problem of circularity arises as the Swedish transport policy 
goals are conflicting, and hence must be subject to trade-offs, while several of the goals 
themselves entail statements on how to prioritize or restrain goals in case of conflict.

Paper II analyzes rationality in road safety policy. Problematic features are identified and 
discussed. The paper argues that the Swedish road safety goal is rational, since it is action-
guiding and achievement-inducing.

Paper III includes a model of rational choice under risk with biased risk perception. Under 
certain plausible conditions, a regulator should raise the population’s risk exposure. By 
deteriorating the environment the regulator can motivate drivers to choose behaviour that is 
less biased.

Paper IV provides a formal representation of goal systems. The focus is on three properties: 
consistency, conflict, and coherence. It is argued that consistency is adequately regarded as a 
property relative to the decision situation or, more specifically, the set of alternatives that the 
agent faces. Conflict is adequately regarded as a relation over subsets of a given goal system 
and should likewise be regarded as relative to the set of alternative that the agent faces. 
Coherence is given a probabilistic interpretation, based on a support relation over subsets of 
goal systems.

Paper V investigates problems associated with standard deontic logic. A deontic predicate is 
derived, which avoids some of the major paradoxes in the area. In particular, paradoxes 
occurring when one obligation is derived by logical necessity from another obligation are 
dealt with.

**Keywords:** goals; transport policy; road safety; coherence; action logic; deontic logic

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Among philosophers from other departments, I wish to thank Jan Odelstad for scrutinizing my licentiate thesis in 2006. Paper IV is a direct outcome of a graduate course in epistemology at Lund University, led by Erik J. Olsson and Bengt Hansson the same year. Wlodek Rabinowicz supervised my master’s thesis in practical philosophy in 2003 and encouraged me to proceed to graduate studies.

From outside the realm of philosophy, I have benefited from comments by Patrik Nylander on Paper I. At the initial stage of the project, I benefited from discussion with an expert panel including Lars-Göran Mattsson, Staffan Widlert, and Per Norman. Special thanks to Jakob Nordin at the department of physics, Stockholm University, for helping me draw those nice graphs in Paper III.

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Stockholm, February 2009
Holger Rosencrantz
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Introduction

Goals are fundamental inputs to many decision problems. Transport policy is an area that illustrates this. Management of transport infrastructure involves difficult decisions. Major investments in, for example, new roads or railways compete for public resources; benefits are to be appropriately distributed; and negative effects, in terms of safety and the environment, are to be minimised. In a system as complex and important as a national transport system, with actors involving industrial organisations and individual drivers as well as politicians and administrators, the concept of rational policy decisions is well worth investigating.

In Sweden transport policy is formulated in terms of goals, which are explicitly formulated in official documents (Gov. Bill 1996/97:137; Gov. Bill 1997/98:56; Gov. Bill 2001/02:20). Sweden is not unique in this respect, since national and international transport policy goals also exist elsewhere. Road safety goals have received much attention internationally (Peden et al., 2004). In Finland, transport policy goals concerning financing, regional success, environmental impact, and traffic safety have been formulated (Kommunikationsministeriet, 2008). Similary transport policy goal structures can be found in Norway and the Netherlands (SIKA, 2008a).1 Policy goals of this kind guide strategies and constitute criteria for performance evaluation. However, although a rational model of planning presumably entails an approach aiming at social welfare and justice, national policy goals are set on a political level and goal conflicts are often resolved by political – rather than economical – tradeoffs.

Given this context, questions of a philosophical nature appear relevant for both specific and general topics. Is it irrational to set seemingly utopian and unachievable goals, such as the vision to reduce road traffic fatalities to zero? If not, is there is a price on human lives (Elvik, 1999a; Elvik 2003)? What importance should be given to cost-benefit analyses; should they be viewed as a moral standard or as a decision procedure (Adler & Posner, 1999; Hubin, 1994)? How should positive and negative effects of congestion pricing be distributed; what would be fair?

1. Aim and scope of the thesis

This thesis aims at investigating rationality of transport policy decisions, including goal-setting and performance evaluation. More generally, the thesis aims at developing new, alternative approaches and methods based on suggestions and ideas originating from moral philosophy and philosophical decision theory. There are good reasons why transport research and transport policy could benefit from an investigation with such an aim. Setting of goals is a political issue and methods of evaluations are economical issues. But justifications of both are, at least partly, philosophical issues. Any reference to welfare or justice, for example, relates to classical questions of ethics and political philosophy – namely what constitutes a good life and a good society (Griffin, 1986; Rawls, 1971). The concept of rationality, in turn, is a main concern of decision theory as well as of moral philosophy – namely what constitutes norms of choices and reasons for actions (Levi, 1997; Parfit, 1984).2

1 There are even more internationally adopted goals and targets that are not associated, or only partly associated, with transport policy. Noteworthy examples include objectives of environmental protection and of poverty elimination (UNDP, 2000; Smith & Todaro, 2006).

2 The term “decision theory” is sometimes narrowly referred to as the theory of rational decisions under risk, uncertainty, and ignorance (e.g., Mattsson, 2005). In this thesis, however, the scope of decision theory is taken to
It is an aim of this thesis to make a constructive contribution to problems of practical concern, that are, at the same time, philosophically interesting. This is what is commonly referred to as “applied philosophy”. Applied philosophy requires identification and understanding of problems of practical concern, and should ideally result in contributions that complement or even replace contributions made by other disciplines (in this case, primarily economics and other social sciences). By its very nature, therefore, the aim of making constructive philosophical contributions to practical problems is ambitious, and demands that the researcher approaches the task with realistic expectations and with respect for contributions from other disciplines.

The philosophy of traffic and transportation is not a very big area and there is still much pioneering work to be done. However, a few topics should be mentioned. One of the first primarily philosophical works, with a focus on ethical theory, was published in Denmark in the late 1990s (Zeitler, 1997). An investigation on the redistribution of responsibilities for automobile safety during 1960-2000 has been published in the United States (Wetmore, 2003). Another notable topic is ethical analysis on moral responsibility in traffic safety (Nihlén Fahlquist, 2005; Nihlén Fahlquist, 2006a; Nihlén Fahlquist, 2006b; Nihlén Fahlquist, 2007). There is also ongoing work about the ethics of traffic research and about the framing of decisions in the transport sector. All these different research projects look at, or are at any rate related to, goals within the transport sector.

There are different kinds of goals. A goal, or a set of several goals, may belong to an individual or to a collective of individuals. Goals may be implicit or explicit, and they may be more or less precise. Policy goals are generally explicitly formulated and apply for some collective of individuals, but other kinds of goals will also be relevant to much of the discussion in this thesis.

This thesis discusses the concept of rationality in a policy context with particular focus on transport policy goal-setting and decision-making. This includes topics of philosophical decision theory, as well as political philosophy. Furthermore, as exhibited primarily in the last two papers, the scope covers formalization of goal systems and relations between goals. This includes topics in the fields of belief dynamics and deontic logic.

2. Rationality of goals

Goals have certain functions in decision-making – at any rate, there are ways in which goals should function. A goal should be meaningful, or non-trivial, if it is to affect any agent’s decisions and it should not be vague or ambiguous. Furthermore, a goal should make it possible to plan or coordinate actions over time (and, in the case of goals for organisations or societies comprising more than one individual, between individuals). To put it more generally, a goal should say or imply something about how the agent who has the goal should act. The general requirement that goals should be action-guiding has been proposed in the discussion on rationality of goals (Edvardsson & Hansson, 2005). More specifically, the requirement of being action-guiding means that goals must satisfy three rationality criteria: precision, evaluability, and approachability. In addition, rational goals must also be motivating, since no agent would want to achieve or even be interested in pursuing goals that are not motivating.

include a wider range of situations, including decisions under certainty, group decisions, and games (Levi, 1986; Luce & Raiffa, 1957; Resnik, 1987).
These four criteria resemble the five criteria behind the mnemonic SMART (i.e., objectives should be Specific, Measurable, Achievable, Realistic, and Time-bound), often used in project management in public services (e.g., van Herten & Gunning-Schepers, 2000). Other criteria may appropriately describe the requirement that goals should guide actions, but it seems clear that action-guiding goals must provide the agent with information and be adapted to the agent’s abilities; goals must be meaningful in the sense that they inform the agent on how to act and how to evaluate acts, and in the sense that the goal is relevant to choices between alternative actions that are feasible for the agent.

The philosophical notion of rationality covers both theoretical (knowledge-related) and practical (action-related) aspects (Mele & Rawling, 2004; Spohn, 2002). Practical rationality is often defined in terms of goals, either political goals or individual goals. Although there is much literature on rational decisions and actions relative to given goals, surprisingly little has been written about the rationality of goals themselves. Actions are sometimes assessed as rational relative to goals; an action is rational if it is expected to lead to the achievement of the agent’s goals. Instrumental rationality, the capacity to choose the most efficient means to achieve given goals, represents a reasonable but rather narrow concept of rationality (cf. Simon, 1983). An “efficient” means, in the instrumental sense, need not be optimal – as made famous by the concept of “satisficing” rationality (Simon, 1997; Rubinstein, 1998). Still, an underlying assumption is that ends are rational in themselves – or, at any rate, that it is not meaningful to refer to goals as “rational” or “irrational”.

Some writers have explicitly stressed this assumption. It has been said:

It cannot be too strongly emphasized that there are no criteria for the rationality of ends as such other than the condition of consistency. Ends are completely arbitrary. To prefer highly dispersed random outcomes may seem irrational to the prudent, but for somebody with this penchant, there is nothing irrational about it. This area is like that of tastes: they are what they are, and differ from one person to the next. (Allais, 1953[1979], p. 70)

In the cases of what might be called “genuine” goals, goals that truly are ends in themselves and not means to other ends, this position seems plausible at first sight; if a goal is set without reference to any other goal, and if the goal is consistent with the other goals that the agent has, how can we say that it is irrational? Amartya Sen has argued that a person whose goal it is to cut off her own toes with a blunt knife would be better off by revising the goal to cut off the toes, rather than by optimizing the goal by using a sharper knife, and that therefore this goal may be said to be irrational (Sen, 2002). But this goal can be said to be irrational only if it is understood that the goal is a means to another goal, namely to become somehow “better off”, and not if it is understood that the goal is strictly an end in itself. It is true that the person in Sen’s example seems irrational. But if she maintains that her goal is genuine and an end in itself, then there seems to be no ground for criticism in terms of rationality.

On the instrumental account, as expressed by Allais, goal systems are rational if and only if they are consistent. And it certainly seems plausible to say that goals are irrational when they are contradictory, or in some other way stand against each other. But how useful is this criterion? Two distinct cases of inconsistency can be identified. Logical inconsistency of goals certainly seems irrational, but would be rare. It would be irrational to set a goal to reduce road traffic fatalities to zero while at the same time setting another goal to increase road traffic fatalities to a number greater than zero, but cases of this kind are rare in practice. Contingent inconsistency of goals may be more common, but it is doubtful whether such inconsistencies ought to count as irrational. A goal to reduce road traffic fatalities to zero may
be in conflict with an accessibility goal to make people able to drive faster on the roads, or
safety may in some other way be in conflict with accessibility, but mere goal conflict is not a
sign of irrationality.

3. How should goal conflicts be rationally managed?
Transport is a policy area in which conflicts between goals are of particular concern.
Examples include goals of road safety and environmental protection. Such goals, primarily
concerned with the negative effects of traffic and transportation, often come into conflict with
accessibility or quality – goals primarily concerned with the positive effects of traffic and
transportation. In these contexts, some seemingly rather uncompromising attitudes have been
expressed. The Swedish road safety goal, for example, explicitly states that it is
“unacceptable” that anyone is killed or seriously injured as a consequence of road traffic
accidents (Gov. Bill 1996/97:137). Similar road safety goals have been adopted in Denmark
and Norway (Færdselssikkerhedskommissionen, 2002; Steinset et al., 2002). The widely
influential statement of the Precautionary Principle in the Rio Declaration of 1992 represents
a stringent attitude in assessments of uncertainties concerning large-scale environmental
impacts (UNCED, 1993). And the definition of sustainability as “development that meets the
needs of the present without compromising the ability of future generations to meet their own
needs” is an explicit statement of an uncompromising attitude (Brundtland Commission,
1987).

However, the word “compromising” in the notion of sustainability may be given several
different interpretations (cf. Chichilnisky, 1996; Heal, 1998). Likewise, the notion that some
consequences of road traffic accidents are “unacceptable” has been interpreted differently by
different authors; some have interpreted it as a lexicographical preference ordering, whereas
others have interpreted it simply as placing a high weight on road safety (cf. Elvik, 1999a;
Härsmann et al., 2002). There is therefore some uncertainty as regards the notion of
compromising and the notion of acceptability, and it is sometimes unclear what the notions
imply for the management of goal conflicts.

Even though a pragmatic interpretation of the road safety goal involves short-term
compromising with other goals, identifying the “optimal” level of accident risk poses a
particular problem: To what extent should a regulator manipulate the risk level, when
individual drivers themselves voluntarily choose risk levels according to their own tastes?
Drivers do not unconditionally minimize risks, but make trade-offs between safety and other
goods, such as the convenience of driving fast and arriving on time. For example: Mandatory
wearing of seat belts reduces the likelihood of death or injury in case an accident happens, but
makes people drive less cautiously (Wilde, 1994). It has also been shown that cars outfitted
with antilock brakes are driven faster, more carelessly, and closer to the car in front, braked
more abruptly, and have no lower accident rate per hour of exposure than cars without these
devices (Fosser et al., 1996; Sagberg et al., 1997). Cars fitted with studded tires, similarly, are
driven faster on slippery roads. Thus, studded tires only marginally effect accident rates
(Elvik, 1999b). Wider road design has been shown to increase people’s speed and lane
position, offsetting potential safety effects from changing road width (van Driel et al., 2004;
Lewis-Evans & Charlton, 2006). Last, investigations showed that driver training or a
mandatory course of driving on slippery roads does not reduce accident risk (Christensen &
Glad, 1996).
In addition to the evidence that individuals voluntarily choose to increase risks in order to attain benefits of speed, there are empirical studies suggesting that individuals are often unable to perceive risks adequately; that is, individuals tend to overcompensate risks when they try to optimize them. For example, when lane markings were introduced to improve nighttime road visibility, drivers increased their speed to the extent that they habitually overdrove their headlamps, thus effectively worsening their safety (Cottrell, 1988; Kallberg, 1993; Rumar & Marsh, 1998). In the case of nighttime lane markings, the psychological mechanism underlying such overcompensation has been studied. Owens and Tyrrell (1999) suggested that lane guidance is mediated by visual mechanisms that are less adversely affected by lower light levels, providing drivers with a false sense of their own visual competence. As a consequence, drivers routinely overdrive their headlights because all available feedback tells them they are driving at a safe speed.

The hypothesis that individuals generally optimize, rather than minimize, risks is stressed in risk homeostasis theory (Starmer, 2000; Wilde, 1994). The hypothesis that risks are often underestimated lends support from general observations suggesting mental heuristics leading to large and persistant biases (Kahneman et al., 1982). Paper III combines these two approaches. The paper argues that, under certain conditions, a “deterioration” of the environment may affect people’s behaviour in such a way that the final outcome is beneficial. Regulators may, for example, opt to make a roundabout smaller in order to make people drive more slowly and cautiously.

4. The logic of goals

Goals play a central role in artificial intelligence and multiagent systems. Goal systems are commonly used in existing agent programming languages, and discussed and analyzed in formal agent theories (e.g. Broerse et al., 2002; da Costa Pereira & Tettamanzi, 2007; Dastani & van der Torre, 2002; Rahwan & Amgoud, 2006; Shapiro et al., 2005). Along with philosophical writings in the tradition of theory change (Alchourrón & Bulygin, 1971; Alchourrón et al., 1985; BonJour, 1985; Gärdenfors, 1988; Hansson, 1999; Hansson & Makinson, 1999; Levi, 1980; Levi, 1984), this provides a starting point for investigating and formalizing concepts such as consistency, conflict, and coherence. Goals are similar to beliefs in the sense that they can be expressed as sentences – in the former case as factual statements that are believed to be true, and in the latter case as factual statements that some agent wants to realize. Consequently, there are reasons to investigate epistemological topics in a context of goals.

Allais (1953[1979]) stresses the concept of consistent goals. Millgram (2000) and Edvardsson (2006) have investigated the concept of goal system coherence, though in a non-formal or quasi-formal discussion. In the epistemological literature, it is generally agreed that inconsistent sets of beliefs must be consolidated – i.e., made consistent (Fuhrmann, 1997; Hansson, 1991; Olsson, 1997). There is also an ongoing discussion on how to characterize and measure coherence of belief sets (Hansson, 2006; Hansson & Olsson, 1999; Lewis, 1946; Olsson, 2002; Olsson, 2005; Shogenji, 1999).

One of the points stressed in Paper IV is that the above mentioned epistemological concepts are only conceivable as relative to specific situations; more precisely, it does not make sense to refer to a goal system as inconsistent or incoherent unless additional information about the decision-maker’s situation is (implicitly or explicitly) assumed. Consequently, a complete formal representation of goals must include a logic of action. Paper V involves constructing
such a logic. Writings on the logic of action is already prominent, originating with classical writings of Aristotle, St. Anselm, and David Hume and continuing with contemporary literature in philosophy and artificial intelligence (e.g. Bratman, 1984; Bratman, 2006; Davidson, 1980; Giordano et al., 2000; Hughes et al., 2005; Hughes et al., 2007; Segerberg, 1992; Wooldridge, 2006; Zhang & Foo, 2001).

Since obligations and intentions are closely related to goals, there is a natural connection between action logic and deontic logic. Standard deontic logic, as it is commonly referred to, is based on a semantical construction of possible worlds; an obligation to realize some sentence $p$ holds, it is said, if and only if $p$ is true in every possible “ideal” world (Føllesdal & Hilpinen, 1970; Hansson, 1969; Hansson, 2001; von Wright, 1951; von Wright, 1956; von Wright, 1968; von Wright, 1998). This gives rise to a number of paradoxes (Åqvist, 1994; Åqvist, 1967; Prior, 1954; Prior, 1958; Ross, 1941) that can be avoided by deriving a deontic logic from an action logic.

5. Summary of papers I–V

Paper I discusses the Swedish transport policy goals, and problem of combining policy goals with welfare economics. On an instrumental account, goals are taken for granted as inputs to decision problems, and decisions are assessed as rational to the extent that they result in that goals are achieved. Social welfare, while frequently assessed as a criterion for rational trade-offs between goals, is itself an ambiguous goal. In Sweden, the overall goal for transport policy is to provide a system that is both economically efficient and sustainable in the long term. This overall goal is specified by six sub-goals: (1) an accessible transport system, (2) a high standard of transport quality, (3) safe traffic, (4) a good environment, (5) positive regional development, and (6) equal opportunities. The first two are concerned with promoting the positive effects of the transport system – the purpose why there is a transport system in the first place. The next two sub-goals, in contrast, are concerned with preventing the negative effects of the transport system. Finally, the last two sub-goals express distributive concerns – that positive and negative effects should be fairly distributed between regions and between the sexes. The six goals often come into conflict and trade-offs must be rationally and consistently managed.

Paper II (Rosencrantz et al., 2007), written together with Sven Ove Hansson and Karin Edvardsson, discusses rationality in road safety policy. Sweden’s ambitious road safety goal, “Vision Zero”, has met with much criticism. Among other things, the goal has been accused of being illusory and irrational. The paper states that such accusations of irrationality have been unnecessarily imprecise, since no reference is made to independently developed criteria of rational goal-setting. The paper argues that the Swedish road safety goal is rational, since it is action-guiding and achievement-inducing. The goal satisfies the criteria of precision, evaluability, approachability, and motivity. Nevertheless, some problematic features – such as the lack of temporal precision in the long-term goal and the difficulty of comparing fatalities and serious injuries when evaluating performance – are identified and discussed.

Paper III includes a model of rational choice under risk with biased risk perception. On its basis, it is argued that sometimes, a regulator aiming at maximizing social welfare should raise the population’s risk exposure. It is shown that by deteriorating the environment – i.e. by making it riskier – the regulator can motivate drivers to choose behavior that is less biased. The conditions under which such a beneficial effect exists are investigated. The benefits of such an intervention in a heterogeneous population are investigated.
Paper IV (Rosencrantz, 2008) provides a formal representation of goal systems. The focus is on three properties: consistency, conflict, and coherence. An aim is to attain conceptual clarity of these properties. It is argued that consistency is adequately regarded as a property relative to the decision situation or, more specifically, the set of alternatives that the agent faces. Moreover, as a condition of rationality, consistency is stronger than some writers have claimed. Conflict is adequately regarded as a relation over subsets of a given goal system and should likewise be regarded as relative to the set of alternatives that the agent faces. Coherence is given a probabilistic interpretation, based on a support relation over subsets of goal systems.

Paper V provides an analysis of paradoxes in standard deontic logic. Two features of these paradoxes are pointed out; (1) they involve inference of obligations with arbitrary disjuncts, and (2) they involve failure to properly distinguish between actions and contexts. After an initial presentation of these paradoxes and their sources, the paper constructs a logic of action. A deontic predicate is derived, and it is observed that this predicate does not satisfy all of the axioms of standard deontic logic. In violating these axioms, the predicate avoids the paradoxes.

6. Afterthought

In Paper I and in Paper II, the Swedish transport policy goals are analyzed. Among other topics, problems in policy goal-setting are identified and simplistic views of rational trade-offs are challenged. Two questions may be posed regarding these two papers: Is this philosophy? And in what way does philosophy make a constructive contribution? The easy way to answer these questions is to say that, by virtue of being part of a thesis in philosophy, the two papers are to be classified as philosophical papers and that the constructive contribution may still be difficult to identify. But more can be said about the relation between philosophical activity and practical problems. While the two papers may provide an interesting summary of “philosophical” problems recognized by non-philosophers (or philosophically oriented social scientists) who have analyzed the Swedish transport policy goals, it might be argued that these goals are not suitable as objects for rigorous philosophical scrutiny. The goals have been formulated by people with little philosophical background and are not intended to be evaluated according to philosophical standards. They are intended to be communicated primarily among non-philosophers, and to coordinate actions across agents who likewise lack philosophical training. As such, the goals manifest a notion of rationality that is arguably different from the philosophical notion. They are not to be taken literally, but are mere means of communication between politicians on the one side and administrators or the public on the other side, and it should be admitted that the goals are rhetorically formulated. The question, then, is whether it is in any way more constructive to approach problems in transport policy decision-making or goal-setting from a philosophical point of departure than from the perspective of a social scientist with methods of empirical research and faculties of critical thinking. While the answer to this question is pending, it may be said that these two perspectives are not mutually exclusive; a philosopher may also be a scientist, or a practitioner, and vice versa. Whether Paper I and Paper II are writings in the philosophical tradition, and whether they address problems to which philosophy exclusively has the potential to make a specific contribution, is not as important as whether the arguments they present are of interest to philosophically oriented scholars in general. Neither is the question whether a particular text is “philosophy” as important as the question whether acquaintance with philosophical literature legitimizes claims of expertise, or whether
familiarity with philosophical concepts provides an advantage; while the former question precedes the latter questions, it is of interest only in light of what could be said about the benefits of doing philosophy.

In Paper III, a decision theoretical problem of relevance to transport policy is investigated. The main argument is illustrated by some rather specific functions representing the possibility frontier and the perception bias. It should be emphasized that the argument is not dependent on assumptions that either of these function uniquely represents the decision problem. The general problem consists in combining a set of plausible assumptions with the condition that the net effect is beneficent. Let the probability triangle represent the set of pairs \( \langle p, q \rangle \in [0, 1] \times [0, 1] \) such that \( p + q \leq 1 \). With \( f \) being a real-valued function, and with \( q = f(p) \), the domain of the probability triangle is defined as the set \( \{ p \in [0, 1] : p + f(p) \leq 1 \} \). Then the following general conditions can be formulated:

1. \( f \) is continuous over the domain of the probability triangle. (p. 3).
2. \( f \) is continuously differentiable over the domain of the probability triangle (p. 3).
3. \( f \) is a monotonically increasing function of \( p \) (pp. 3-4).

Since the possibility set demarcated by \( f \) is (strictly) convex (p. 4), it is also assumed that

4. \( f \) is a (strictly) concave function over the domain of the probability triangle.

The assumption that the indifference curves are upward sloping, linear, and parallel follows from the expected utility hypothesis (which in turn follows from the standard assumptions of ordering, continuity, and independence):

- Let \( L \) be a lottery of the form \( \{ p, H, q, A ; 1-p-q, -(A \lor H) \} \).
- Then \( u(L) = p \times u(H) + q \times u(A) + (1-p-q) \times u(-(A \lor H)) \).
- Then \( q = (u(-(H \lor A))) + p \times (u(H) - u(-(H \lor A))) - u(L)/u(-(H \lor A)) - u(A) \).
- With \( u(A), u(H), \) and \( u(-(H \lor A)) \) fixed for each individual, and with \( u(L) \) fixed for each indifference curve, it is then clear that the indifference curves are linear with the slope \( k = dq/dp = (u(H) - u(-(H \lor A)))/(u(-H \lor A) - u(A)) \); note that \( k \) is positive, since \( u(A) > u(-(H \lor H)) > u(H) \).

As for the real-valued function \( b \), each of the three specific functions examined in the paper satisfies the following condition:

5. \( p \leq \frac{db}{dp} \leq 1 \) over the domain \([0, 1]\).

It is also noted in the paper (p. 14) that it is implausible that, for some interval, the agent decreases her risk judgment with increasing risk. This corresponds to the following condition:

6. \( 0 \leq \frac{db}{dp} \) over the domain \([0, 1]\).

Two definitions provide the central concepts of the paper:

- A pair of real-valued functions \( \langle f_\alpha, f_\beta \rangle \) is a risk increase if and only if \( f_\alpha(p) > f_\beta(p) \) for all \( p \) such that \( p + f_\alpha(p) \leq 1 \).
- A pair of real-valued functions \( \langle f_\alpha, f_\beta \rangle \) is \( kb \)-beneficial if and only if \( f_\alpha(b(p_\alpha^*)) < f_\beta(b(p_\beta^*)) \), where \( p_\alpha^* \) and \( p_\beta^* \) are such that \( f_\alpha'(p_\alpha^*) = f_\beta'(p_\beta^*) = k \).

The general argument is that there exists a triple of real-valued functions \( \langle f_\alpha, f_\beta, b \rangle \) and a positive number \( k \) such that:

- (a) each of \( f_\alpha \) and \( f_\beta \) satisfies the conditions (1)-(4),
- (b) \( b \) satisfies the conditions (5)-(6), and
- (c) \( \langle f_\alpha, f_\beta \rangle \) is a \( kb \)-beneficial risk increase.

Since this theorem concerns the existence of a beneficial risk increase under a set of plausible conditions, the argument does not fall with the fact that the observations reported in Table 1 (p. 15) concern specific functions.
In Paper IV and Paper V, formal theories based primarily on belief dynamics and deontic logic are developed. While the focus is on goals and obligations, respectively, the two topics are related; a goal may be interpreted as an obligation to realize a particular state-of-affairs, in the sense that an agent who has a goal ought to achieve it. Hence, the framework in Paper V may be suitable for analyzing and developing the concepts formalized in Paper IV. In particular, the support relation defined in Section 5 of Paper IV may benefit from a more refined logic of action. In this way, the notion of normative coherence could be further developed. A suggestion for further work in this area will briefly be sketched out here. In order to clarify the concepts formalized in Paper IV, the framework provided in Paper V can be expanded such that the decision problem is modeled as a simple belief network. In particular, this can provide a clearer account of the notion in Definition 5.1 that an agent “attempts to realize” a set of sentences. Let $\mathcal{L}_0$, $\mathcal{L}_1$, and $\mathcal{L}$ be defined as in Section 3.1 of Paper V, and let $S$ be a subset of $\mathcal{L}$. Let $p$ be a function from $S'$ to $[0, 1]$, where $S'$ is a set such that

1. If $\alpha \in \mathcal{L}_0 \cap \text{Cn}(S)$, then $\alpha \in S'$.
2. If $m(\phi, \alpha, \beta) \in \text{Cn}(S)$, then $m(\phi, \alpha, \beta) \in S'$.
3. $S'$ is closed under the truth-functional operations $\neg$ and $\land$.
4. Nothing is an element of $S'$, except by virtue of (1)–(3).

Thus, given the additional assumption that $p$ is a probability measure satisfying the usual axioms, the decision problem of Paper IV can be represented by the pair $(S, p)$. In network terminology, each counterfactual outcome $\beta$ is a child of at least three parents: an action $\phi$, a fact $\alpha$, and a subjunctive conditional $m(\phi, \alpha, \beta)$ stating that the outcome would result from performing the action when the fact holds. The conditional probability that $\beta$ would be the outcome of performing the action $\phi$ can therefore be calculated as $P_S(\beta|\phi) = \sum \{p(\alpha \land m(\phi, \alpha, \beta)) : \alpha \in T\}$, where $T$ is a set such that

1. $\{\text{Cn}(\alpha) : \alpha \in T\} = \mathcal{L}_1 \cap S' \downarrow \bot$. (The operator Cn is a map from $T$ to the set of maximally consistent subset of $\mathcal{L}_1 \cap S'$.)
2. If $\alpha, \alpha' \in T$, then $\text{Cn}(\{\alpha\}) \neq \text{Cn}(\{\alpha'\})$. (There is no pair of logically equivalent sentences in $T$.)

The notion that an agent “attempts to realize” a set $X$ of sentences, denoted $\text{att}(X)$ in Definition 5.1, can now be defined as the disjunction of those actions that maximize the probability of realizing $X$; a plausible interpretation of this notion is that the agent performs one action among those actions that maximize the probability of realizing $X$. This can be formally expressed as $\text{atts}_S(X) = \lor \{\phi \in A_S : (\forall \phi \in A_S)(P_S(\land Y|\phi) \leq P_S(\land Y|\phi))\}$, where $A_S = \{\phi \in \mathcal{L}_1 : (\exists \alpha, \beta \in \mathcal{L}_1)(m(\phi, \alpha, \beta) \in S')\}$. In the special case where there is a unique action that maximizes the probability of realizing $X$, $\text{atts}_S(X)$ will of course be equal to this action. Section 5 of Paper IV can now be reformulated with $P(\land Y|\text{att}(X)) = P_S(\land Y|\text{atts}_S(X))$. This suggested course for further work is yet to be elaborated. The main benefits of Paper V may therefore be that it provides a framework preceding further work relating to the concepts formalized at the end of Paper IV, and the results regarding paradoxes in Standard Deontic Logic may turn out to be but a spinoff in the work towards a complete account of goal system coherence.

In short, much more can be done. While the problems addressed in this thesis are indeed intriguing and leave many new questions to be answered, however, it is time to conclude; further work might have to wait, but hopefully not for too long.
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