32 DESIGN BY OPTIMISATION
AN OPEN DECISION-MAKING APPROACH

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In this contribution it is assumed that designers in architecture and urban planning constantly strive to improve their design. In doing so, they act as rational actors who, as soon as they see opportunities to improve proposals, will no longer be satisfied with their existing ones. Designers will continually strive to achieve the best result possible. In other words, they optimise outcome of their work. This process is referred to as design by optimisation, and the outcome as the optimum design, the definitions of which I shall build into this Chapter.

Some 25 years ago, the design process in architecture and urban planning was almost always headed by one, perhaps several architects, or in the case of large-scale projects, several urban designers. Today, however, a comprehensive design team consisting of all organisations involved is responsible for the process and its results. In consequence, nowadays designers other than architects also have direct and strong influence on the design: structural engineers, costing experts, traffic engineers, building contractors, governmental planners, also users, investors and local residents.

For co-operation between all these experts, specialists and decision-makers a new methodology, called 'Open Design' has been developed by the author. This methodology reflects the necessarily 'multi-actor' or 'multi-party' negotiation and decision-making in current architectural and urban design.[a]

In Open Design, the terms 'designer', 'group', and 'optimum design' are interpreted more broadly than is common in established design methodology. A designer is anyone who has an impact on a design, whether professional or not. The group of designers, therefore, also includes non-professional designers. Which design result is considered optimal is decided jointly.

The Open Design methodology consciously distances itself from the position adopted by many professional designers, who believe that professional group optimisation must be regarded as distinct from, and a necessary pre-requisite for, social group optimisation. In other words, the study sees the optimum social design not as deriviation from optimum professional design. Professional designers often refer to the social optimum as a political compromise. Such a distinction can not be drawn, and the order in which these two optima come about can not be dictated. A professional design also incorporates social views of the professionals and therefore implicitly includes their social group optimum. And a social design incorporates technical views of the non-professionals, thus implicitly including their technical group optimum. They are therefore two aspects of the same design.

32.1 THE DESIGNER AS HOMO ECONOMICUS

Optimisation is, within the context of rational action, goal-orientated. Rational, goal-orientated action differs from traditional action determined by custom. It also differs from affective action, which involves unrestricted response to external stimuli and from idealistic action, whereby the individual does what he considers to be his duty, irrespective of results.[b]

As far as rational goal-orientated action is concerned, one distinguishes between economic and non-economic goals. Economic goals are those which require use of scarce resources that could be used alternatively. All other goals are non-economic. It is possible for economic and non-economic goals to conflict. For instance, if a private individual seeks to meet his accommodation needs rationally and economically by having an affordable (cheap) house designed and built, this might conflict with his non-economic goals regarding the (expensive) aesthetic quality and status of the house.

a Loon, P.P. van (1998) *Interorganisational design, a new approach to team design in architecture and urban planning;* Gunsteren, L.A. van and P.P. van Loon (2000) *Open design, a collaborative approch to architecture.*

b M. Weber, 1922 in: Doel, J. van den (1978) *Demokratie en Welvaartstheorie.*

In the seventies it was assumed that, in order to be rational, an actor acts as a Homo Economicus who[a]:

- is fully informed about the various economic options;
- operates completely rationally;
- aims to optimise the expected economic value;
- and is influenced by measurable results only.

These assumptions later came under heavy criticism. Complete information is never available, no one behaves in a completely rational way, people do not always strive to achieve the best result, and results, also not to be measured, play an important rôle. As more insight was gained into the actual state of affairs, it was concluded that an actor is not always consistent and focused. Human action also involves intuition, tradition, trust and impulse. Goals are often determined after choices have been made. Decisions are, therefore, often made in an unpredictable order.[b]

32.2 GOAL ORIENTATED DESIGN IS NOT DOOMED TO FAILURE

This is not to say that every method in design and decision-making, which assumes that an actor tackles his problems in a targeted and focused way is doomed to failure.[c] One can regard many, if not most, activities as focused. Nevertheless, one should be aware of the fact that there are, in reality, situations in which designs and decisions come about without explicit goals. In these cases appropriate goals are set both during and after the design/decision-making process. In such situations it is still possible to reconstruct the relationship between goal and solution.

In decision-making theory, such situations are said to involve 'limited rationality', indicating the limitations of people as decision-makers.[d] These limitations are connected to: the image of a decision-making problem (lack of knowledge means that the problem is not always a 'given fact' and is therefore difficult to define and the image is limited and subjective); the availability of solutions (alternative solutions are not usually provided, but have to be sought or devised); the awareness of the effects of solutions (It is often not known what can be achieved with a particular solution).

32.3 DESIGN AT A SATISFACTORY LEVEL

Herbert Simon[e] postulated that it is not always possible to maximise profits, and introduced the idea of the 'satisfying' principle (minimising complications and risks).[f] This holds that actors strive only to achieve a limited, usually concrete level of aspiration, because their image of a problem is limited by incomplete knowledge and shortage of time to spent on the problem solving process and because solutions still have to be devised and the effects of the solutions are not entirely known. The criterion is then not 'the house must be as big as possible' but 'the house must have 200 m^2 of floor space'.

Describing decision criteria as specific levels of aspiration offers important practical and theoretical advantages, even if those involved have only a vague notion how their situation could be improved. It is an unambiguous means of measuring whether the goal has been achieved.

Van den Doel (1978, p. 40) states that the fact that formulating decision criteria as 'levels of aspiration' offers advantages must not automatically lead to the conclusion that individuals do not seek to achieve a maximum. The inaccuracy of this conclusion can be demonstrated by distinguishing between subjective and objective rationality. A decision is subjectively rational, if a decision-maker attempts to maximise his goal function. It is objectively rational, if this maximum is actually achieved. The gap between subjective and objective rationality arises partly because of lack of information about alternatives and their implications, and partly

a Davis, G.B. and M.H. Olson (1985) *Management information systems*. p.231
b Boersma, S.K.T. (1989) *Beslissingsondersteunende systemen; een praktijkgerichte ontwikkelingsmethode*, p. 39
c Doel, J. van den (1978) *Demokratie en Welvaartstheorie*, p. 39
d Boersma, S.K.T. (1989) p.23.
e Simon, H. (1957) *Administrative behavior;* – (1969) *The sciences of the artificial*.
f Boersma, S.K.T. (1989) p. 20-22.

because of the impossibility of taking all information into account. The actor optimises: he looks for the best solution from given, offered or known solutions.

In terms of design this means that the designer attempts to achieve a satisfactory level of design result. Achieving this does not necessarily mean he will always be entirely content. For instance, as soon as he receives more information, his level of aspiration will rise and he will attempt to reach that level.

32.4 THE COMBINATIONAL EXPLOSION OF SUB-DESIGNS

These ideas about optimisation on the part of the individual designer are often also applied to whole design teams. In a team, all members' ideas and proposals are collected, arranged in order of preference and combined with alternative solutions. The team then chooses the best. This represents the basis of what we might call 'classic' (or 'systematic') design methods, most frequently used in practice. These methods developed from a succession of techniques, allowing teams to combine and select more effectively, more efficiently, more rapidly.

However, once design commissions became more complex and teams more inter-disciplinary and larger, the design process began to run aground more frequently. The enormous number of sub-solutions produced in these large teams and the complexity of combining alternatives meant that it became impossible to find solutions satisfactory for everyone. The technical refinement of classic methods, refinements in terms of the calculation procedures for combination and selection, did not solve the problem. On the contrary: they allowed so many possibilities, that they caused a combinational 'explosion' (see page 208). In other words, the calculation time needed to find the best combinations from all possibilities had become so excessive that the process had become virtually unmanageable.

In practice, many professional designers therefore rejected the systematic design methods they had been taught, simply in order 'to make good plans', they then tried to sell using charisma and powers of persuasion. In so doing, they turned their backs to a large extent on team design.

32.5 THE DESIGNER AS HOMO SOCIOLOGICUS

In the shift from classic design methods, based on the individual situation, to the group situation, design methodology overlooked the fact that these methods were based on an excessively narrow definition of rationality: the rationality of Homo economicus of the 1970s. The idea that a decision-maker, or designer, in the process of optimising, rationally compares conflicting preferences and arranges them in a fixed order before choosing the best one and that the designers in a team, in the process of optimising, also make a rational comparison and determine a fixed order, then for all preferences together, before choosing, is too limited for team design.

Later, in the 1980s, rational choice theory showed that rational decision-making in groups could also be structured using a broader definition of rationality. The image of Homo Economicus was replaced by Homo Sociologicus, thus replacing economic rationality with sociological rationality.

Pellikaan and Aarts summarised this by distinguishing between the thick theory of rationality and the thin version.[a] Thick theory assumes maximisation of the outcome and specifies the goals, objectives and preference orderings of actors. Thin theory assumes some sort of maximisation and specifies conditions for the preference orderings of actors, but does not specify any particular goal, objective or preference ordering.

This difference can be illustrated using the well-known Prisoner's Dilemma from decision-making theory (a theoretical formulation of a human dilemma that had already been described by philosophers like Hobbes and Hume).

a Pellikaan, H. and K. Aarts (1996) *Potential and actual social dilemmas, rational choice in survey research*.

		Column – Player	
		Co-operate / do not Confess	Defect / confess
Row – Player	Co-operate / do not confess	Outcome Q (1 year, 1 year) Neither player confesses the major crime; they are tried for minor crimes and get one year each.	Outcome S (20 years, 0 year) The column player turns state's evidence and is freed. The row player is convicted and gets twenty years.
	Defect / confess	Outcome P (0 years, 20 years) The row player turns State's evidence and is freed. The column player is convicted and gets twenty years.	Outcome R (10 years, 10 years) Both players confess, are tried for the major crime and get ten years each.

315 The outcome matrix of the original Prisoner's Dilemma (after: Pellikaan and Aarts, 1996)

		Column – Player	
		Co-operate	Defect
	Co-operate	Outcome Q (3,3).	Outcome S (4,1) a
	Defect	Outcome P (4,1)	Outcome R (2,2)

316 The payoff matrix of the original Prisoner's Dilemma (after: Pellikaan and Aarts, 1996)

In the original Prisoner's Dilemma two players have a choice between two strategies: co-operate (do not confess) or defect (confess). The combination of two players with two possible strategies yields a matrix with four possible cells. Figure 315 is the outcome matrix of this game, describing the physical consequences for every possible combination of choice by both players. The outcomes in figure 315, however, do not imply the dilemma. The dilemma only arises after the players have established their utilities or payoffs for the four outcomes.

The problem in figure 315 is one-dimensional because the players are assumed to consider only the self-regarding motive indicated by the number of years they personally will spend in jail. The self-regarding motive 'prefer a shorter term for yourself to a longer term' leads to the following preference ordering: 0 years > 1 year > 10 years > 20 years. This preference ordering corresponds with P > Q > R > S or, for short, PQRS.

The preference ordering PQRS is the so-called Prisoner's Dilemma or PD-ordering. The PD-ordering is a plausible ordering for every individual placed as a (row-) player in the outcome matrix of figure 315. If both players have a PD-ordering the game becomes a Prisoner's Dilemma. The payoffs in figure 316 define the Prisoner's Dilemma game. Both players have a dominant strategy (Defect), and the result of the game is mutual defection.

The Prisoner's Dilemma was often used to show that methodological individualism and, consequently, individual pursuit of maximisation of utility, leads to a less-than-optimum collective outcome. This justifies the enforcement, from outside the group, of co-operative behaviour that would be beneficial for both players - enforcement by government or management.

These bodies do not decide what the best outcome is; they have no goals or preferences of their own, but enforce co-operation so that the individuals achieve a group optimum.

The PD model is often extrapolated to the N-individuals situation. The number of combinations of strategies then grows exponentially. Without co-operation enforced by some central authority, the collective optimum could never be achieved in an N-individuals group.

However, enforcement of mutual co-operation in groups has led to many drawbacks. Not everyone can be forced to co-operate always. Power to enforce the optimum will be limited in an open, democratic, community. There will be no consensus that people must be forced to co-operate on all collective dilemmas. An alternative for central enforcement was then sought in co-operation on the basis of commitment to others and social norms. But, because people did not always choose to contribute to collective matters, it was not possible to achieve the group optimum in some cases. The search then turned to co-operation based on the notion that iterated choices can generate co-operative behaviour. The rational actor will choose a conditional voluntary co-operative strategy. But, in a large group of actors a common knowledge of each other's behaviour was not feasible. Individual actors still preferred unilateral defection to mutual co-operation.[a]

One common feature of these three types of 'enforced' co-operation is the assumption that each individual is selfish and that this can only be held in check by central authority, commitment to others and social norms. Pellikaan introduced an alternative to this assumption: the actor's viewpoint (based on the thin theory of rationality).

The actor's viewpoint assumes that even given force, commitment to others and social norms, actors can adopt a co-operative attitude. This possibility arises because the individual's efforts to maximise utility do not mean that he seeks to achieve selfish aims. People are not selfish by definition.[b] This implies, that individuals have their own subjective preferences, their own view of the best outcome, and that in a group there will always be several preference orderings for one and the same group dilemma. Only in practice will it become clear whether a specific collective issue that is a dilemma on paper will actually appear so in

a Pellikaan, H. and K. Aarts (1996) *Potential and actual social dilemmas, rational choice in survey research*.
b Pellikaan, H. (1994) *Anarchie, staat en het Prisoner's Dilemma*.

reality. And, conversely, an issue that on paper seems uncontroversial might turn out to be a dilemma in practice.

In short, one cannot say in advance how preferences and goals will be weighted. This can only be established on the basis of concrete actions. I shall look at the optimum inter-organisational design from the actor's viewpoint below. In terms of my study as a whole, this viewpoint means that actors (designers) must, above all, have the opportunity, as they work together, to weigh up their preferences and goals during the design process. The design method they use must cater for this.

32.6 FOUR DEFINITIONS OF THE OPTIMUM DESIGN

No conceptual framework exists within which the term 'optimum design' can be unambiguously defined. Widely varying interpretations and definitions can be found in the literature. I shall divide these interpretations into four categories of conception of the optimum and the optimum design solution:

a. design conception, concerning the optimum form;
b. planning conception, concerning the optimum choice;
c. mathematical conception, concerning the arithmetical optimum;
d. welfare economics conception concerning the optimum distribution.

a. The optimum form

The design conception of optimality and the optimum design can be found in architectural design theory and also in general design methodology. Here, one is concerned with 'good' design, the 'best' design and 'high-quality' design. Architects often use the term 'optimum form'. The differing theoretical and methodological bases are found mainly in design and design method manuals.[a]

The design conception can be characterised by three aspects of the optimality of a design. The first concerns optimum quality; mainly the architect's concern. Architects believe that their most important task is to create a design of the highest possible architectural quality. In their view, this quality is defined in the debate among architects themselves and between architects and their critics. This determines the different movements, what style is acceptable, and what is regarded as good and bad quality (see legislation governing the architectural profession).[b] The best designs are those, which the architectural profession and its critics regard as the best. A similar process is found in the arts (visual, music, dance, etc.). It is often said that the process has to work in this way because outsiders (principals and users) do not know what 'architectural quality' is. Only the professionals can decide this.

The second aspect concerns the optimum selection and combination of sub-solutions, defined by design theorists. They hold that an optimum design can be achieved only through an optimum design process. The design process is optimum only, if all sub-solutions are first systematically and explicitly collected and selected, after which the selected sub-solutions are gradually combined. It is recognised that the choices made during the selection and combination process are determined not only by the requirements the new product will have to meet (never clear and comprehensive), but also by the inventiveness of the designer and the generally accepted wisdom at that moment about what is best, or what is normal and *en vogue*.

The third aspect involves meeting the requirements the optimum way, the most practical of the three. It is assumed here that the requirements of a principal have been formulated in such a way that the designer knows exactly to what extent his design meets them. They need not be comprehensive and explicit right from the outset; they can be finalised during the process. However, principal and designer must stick to their rôles: the principal formulates requirements, designer finds the solutions.

a Jones, J.C. (1970) *Design methods: seeds of human futures;* Broadbent, G. (1973) *Design in architecture: architecture and the human sciences;* Foqué, R. (1975) *Ontwerpsystemen, een inleiding tot de ontwerptheorie;* Lawson, B.R. (1990) *How designers think, the design process demystified.*

b VROM, Ministerie van (1987) *Wet op de Architectentitel*.

In the past many attempts were made to link the three aspects methodologically. The systems approach, particularly its mathematical side, and operations research were usually taken as a basis. The idea was not to create mathematical models for the design process but to analyse it systematically, almost mathematically, and divide it into a large number of sub-processes. Methods for structuring the individual sub-processes were developed, so that optimum partial results could be achieved. A whole generation of design methods emerged this way in the 1960s. Jones (1970) managed to bring some order to the chaos created by this proliferation of new design methods.

However, after many studies and experiments, it became clear that this was no way to determine the conditions required for an optimum design. It was found that an optimum design is not simply the sum of optimum sub-designs. Foqué maintains that the attempts at integration were too technocratic, based on an exclusive belief in the logical analytical thought process, in total rationalisation of action and in 'scientific method'.[a] This negative conclusion dogged the development of design theory and design methodology for many years. In the 1980s, with the advent of computer aided design techniques (CAD), it was given new life. However, renewed study of optimum design has yet to get off the ground.[b]

b. The optimum choice

The planning conception of optimality and the optimum design can be found in planning theory. This conception is an elaboration of one aspect of the design conception: optimum combination of sub-solutions. Planners refer to the 'optimum choice from alternative possibilities'.

Planning theory assumes that the problems planners are called upon to solve are ill defined. There is uncertainty both as to the environment within which the problems arise and as to the values and objectives one must attempt to achieve. This means the problems cannot be fully quantified and, consequently, quantitative planning techniques cannot be used. In order to achieve an optimum outcome nevertheless, a 'rational planning process' must be followed: *"enumerate the finite number of alternative programmes, evaluate them and select one, thereby invoking a decision rule like (mathematical, PPvL) optimisation"*.[c]

Several authors developed prescriptive models for the planning process along these lines.[d] They see it not as a strict timetable of activities which is determined in advance, but as a learning process: the more problems come to light, and the more alternative solutions are devised, the better one will understand the problem and the better solutions one will find. If this process is structured systematically and rationally, the best (optimum) plan comes about 'automatically'.

c. The arithmetical optimum

The mathematical conception of optimality and the optimum design can be found, inter alia, in operations research (OR), where the term arithmetical optimum is most commonly used.[e] Operations research is *"the application of scientific methods, techniques and tools to problems involving the operations of a system such as to provide those in control of the system with optimal solutions to the problem"*.[f] Mathematical decision-making models are central. Operations research is concerned with 'the scientific method', i.e. 'a scientific (typically mathematical) model' which reflects the essence of how a real decision-making problem is constructed, and can then be used to calculate the optimum outcome. It is assumed that it is possible to create a mathematical representation of reality allowing mathematically optimum solutions to be derived valid in terms of that reality.

In operations research a number of models have been devised for various types of decision-making problems.[g] Although these models are complicated from a mathematical point of view (practical problems are always complex), their basic structure is simple.[h] This structure can best be illustrated using the linear programming model (LP model).

a Foqué, R. (1975) *Ontwerpsystemen, een inleiding tot de ontwerptheorie,* p.63.
b Loon, P.P. van (1998) *Interorganisational design, a new approach to team design in architecture and urban planning*.
c Faludi, A. (1973) *Planning Theory*.
d Friend, J.K. and W.N. Jessop (1969) *Local government and strategic choice, an operational research approach to the process of public planning;* McLoughlin, J.B. (1969) *Urban and regional planning, a systems approach;* Chadwick, G. (1971) *A systems view of planning, towards a theory of the urban and regional planning process*.
e Ackoff, R.L. and M.W. Sasieni (1968) *Fundamentals of operations research*.
f Boersma, S.K.T. (1989) *Beslissingsondersteunende systemen; een praktijkgerichte ontwikkelingsmethode*, p. 18
g Ackoff, R.L. and M.W. Sasieni (1968)*;* Wagner, H. (1972) *Principles of operations research*.
h Boersma, S.K.T. (1989) p. 52-54.

The LP model consists of a set of linear equations (equalities and inequalities) (see page 221). This model can be solved mathematically using the simplex algorithm (see page 223). Its application is known as linear programming: the determination (systematic calculation) of the minimum or maximum value of a linear function (objective function) in the area defined by the linear equations (constraints). The problem faced by the housing association at the end of this Chapter is an example.

In OR, the mathematical definition of the optimum design is fairly simple: the outcome of the mathematical model whose value for the objective function is best, i.e. highest in the case of maximisation, or lowest in the case of minimisation.

Mathematical optimisation is used for many economic and commercial problems. In such cases, mainly financial and organisational goals are optimised: maximum profit, most efficient allocation of responsibilities, fastest production flow. It has also been used in building and urban development, and again in financial and technical objectives (like the maximum number of houses in area B, optimum division of floor space and land use, minimisation of energy consumption, etc.).[a] Goals concerning things like quality of the living environment, equitable distribution of space and preservation of existing culture or environment do not figure. 'Soft' social interests have always been put off by the technical nature of mathematical optimisation. This is not justifiable, since quality, equity and the like also lend themselves to mathematical optimisation.[b]

d. The optimum distribution

The last conception of optimality and the optimum design is derived from 'welfare theory'. As far as I am aware, welfare theory is not concerned with design - unfortunately, since this theory could have important implications for decentralised design, especially design projects that have to be completed in a dynamic decision-making environment. Welfare theory allows a link between democratic decision-making on one hand, and design within a team on the other.

Welfare theory is part of economics. Its exponents concern themselves with group welfare, by which they mean not the material wealth in itself of a particular group but the group's welfare to the extent that it is dependent on scarce (economic) resources. Welfare theory studies the allocation of resources, usually in the form of public goods, within a group (a society), including both costs and benefits associated with a particular allocation.[c]

Pareto's criterion provides a scale for measuring increase in the collective welfare of a group.[d] It is deemed to have increased if the welfare of one or more members of the group increases, without diminishing the welfare of other members. The criterion not only comprises a measure of the direction of change, but also its end point. According to it, collective welfare is optimal as soon as it is no longer possible to increase the welfare of one or more individuals without decreasing that of one or more of the others.

Pareto's criterion does not imply a value judgement.[e] It does not dictate that collective welfare must increase, but merely offers a means of measuring increase. It must be known which groups are enjoying the increase. *"If, for instance, it is only individuals with a relatively high income who profit from an increase in welfare, the change merely accentuates the unequal distribution of wealth and can be rejected on these grounds, despite the fact that Pareto's criterion has been met"*.[f]

If a design is regarded as a plan for distribution of costs and benefits among parties involved, Pareto's criterion can be applied. The design is then optimum, when it can no longer be improved to the benefit of one or more of those involved without diminishing the benefits enjoyed by one or more of the others, benefits they would enjoy if one of the earlier versions of the plan were implemented.

a Catanese, A.J. (1972) *Scientific methods of urban analysis;* Lee, C. (1973) *Models in planning, an introduction to the use of quantitative models in planning;* Lee, C. (1973) *Requiem for large scale models;* Radford, A.D. and J. Gero (1988) *Design by optimization in architecture, building and construction*.

b See: Gunsteren, L.A. van and P.P. van Loon (2000) *Open design, a collaborative approch to architecture;* Loon, P.P. van (2000) *Design by optimization*.

c Doel, J. van den (1978) *Demokratie en Welvaartstheorie*, p. 22.

d Pareto (1906), in Doel, J. van den (1978) p. 59.

e Doel, J. van den (1978) p. 60.

f Idem.

Practical objections to Pareto's criterion arise from the fact that changes in welfare seldom meet the criterion, since almost every gain for some entails loss for others. Van den Doel mentions the 'compensation principle' formulated to overcome these objections.[a] This principle involves assessing whether the 'winners' are able to compensate the loss suffered by the 'losers'. *"If the winners enjoy such a large profit that, after the losers have been compensated for their loss, a net profit still remains, it may be said that the change in welfare is potentially an improvement in terms of Pareto's criterion"*.

32.7 THE OPTIMUM DISTRIBUTION INTEGRATED WITH THE ARITHMETIC OPTIMUM

The four conceptions can be integrated into one definition by expanding the welfare conception to encompass the others.

The welfare conception and Pareto's criterion are used in practice only to discuss actual changes in collective welfare. But, the theory can also be used to analyse welfare changes in a 'designed', not yet effected, distribution of costs and benefits, as indicated above. The theory is then applied during the process in which a group (society) makes and discusses proposals for allocating the finite resources available. The final proposal accepted by the group can then be put into effect and separately evaluated in terms of welfare theory.

In this context, there is a major difference between the design and the implementation stage. At the design stage, the group can freely put forward and discuss proposals. Positive and negative impacts on collective welfare exist only on paper and are therefore intangible. This freedom no longer exists at the implementation stage, since each action has a tangible effect.

If Pareto's criterion is used at the design stage to measure changes, the group can explore all kinds of alternative welfare effects and is still free to compare them. At the implementation stage, the existing level of welfare is the benchmark for Pareto's criterion. At the design stage, the group can decide on its own benchmark, what it will take as minimum constraint. Pareto's criterion can therefore be expanded for the design stage, with the following result:

Collective welfare might increase in response to the implementation of a particular design, if the level of welfare of one or more members of the group increases without causing that of one or more other members to fall below a minimum which these members have set themselves.

This implies that part of the group might enjoy a lower level of welfare than at the outset, since the lower limit they have set might be below present level. It might, however, be higher, if the members concerned feel that there should be a certain minimum increase in actual welfare. The optimum design can then be defined as follows:

The optimum design is achieved when the level of welfare of one or more members of the group can no longer be raised without causing that of one or more other members to fall below the new minimum.

The mathematical conception can be brought in at this juncture, although with an altered view of the rôle of mathematical models in finding solutions (or creating designs).

Normally, a tried and tested model will be used to solve a particular problem. The mathematical method, the main structure and most of the model equations have already been determined. Often, many of the inputs are delivered along with the model as fixed data. Users can generate alternative outcomes only by using variations in the free data of the model. The calculation technique assures that these outcomes represent the mathematical optimum. It is therefore virtually impossible for users not sufficiently versed in construction of mathematical models to use the model to find the optimum according to Pareto. The fixed structure and fixed data make it difficult for them to perform the necessary exercises within the upper and lower constraints of the solution space. This is, however, possible if mathematical methods and techniques are used in such a way, that the design team in principle determines and con-

a Doel, J. van den (1978) *Demokratie en Welvaartstheorie*, p. 61

trols everything in the mathematical description of solution space and constraints. The team must have at all times the opportunity to make changes to the mathematical model (equations, structure and data). The mathematical methods and techniques form no obstacle in themselves. A problem arises when a model has many fixed components incorporated by the individual who devised the model, on his own authority, on the grounds that this was the only - mathematically sound - way.

A mathematical description of the optimum group design, which is in line with the welfare definition, might read as follows:

The design is optimal if the value of the objective function cannot be raised (in the case of maximisation) or lowered (in the case of minimisation) without breaching the limits set by those involved.

One example of this is the solution to the problem faced by the housing association in the following.

32.8 THE HOUSING ASSOCIATION'S DECISION MAKING PROBLEM

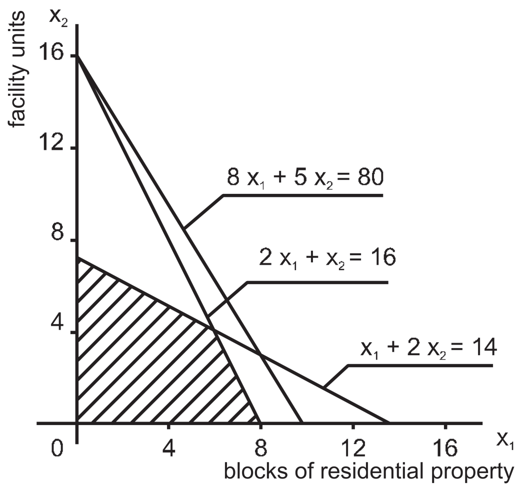
We briefly repeat the exercise of page 221. A housing association wants to build a number of blocks of residential property and facility units (shops, school, social and cultural centre, etc.) on a particular site. The site covers 14,000 m^2. The association hopes to complete the project within 16 months. A block (construction time 2 months) covers 1,000 m^2, while a facility unit (construction time 1 month) covers 2,000 m^2. A residential block costs 8.10^6 guilders, and a facility unit costs 5.10^6 guilders; the overall budget is 80.10^6 guilders. It is not necessary to cover the entire site. A survey has been conducted among future residents. This revealed that they value housing blocks and facilities at a ratio of 5:3. The aim is to ensure that the future residents are as pleased with their neighbourhood as possible.[a]

This problem can be represented mathematically in an LP model. X_1 is the number of blocks of residential property and X_2 the number of facility units. Two decision-makers are involved in this problem: the housing association and the future residents. The housing association decides what site area is to be built on, how long the building work will take how much it will cost and sets out the timetable for the project. The future residents decide on their opinion of the houses and facilities. These give the decision variables. The input variables are the total budget (80.10^6 guilders maximum) and the land available (14,000 m^2 maximum). They have been determined by the local authority within the constraints of its overall urban plan and the regulations governing its housing budget. The future residents want to see their views taken into account to the greatest possible extent, so $5\,X_1 + 3\,X_2$ must be maximised. The housing association wants to complete the project within 16 months and sticks to its decisions regarding construction costs, construction time and site area. These are the goals; they can be represented as follows:

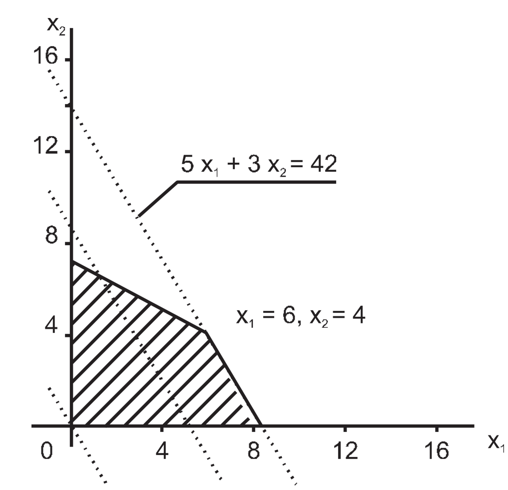
maximise:	$5\,X_1$	$+$	$3\,X_2$			(appreciation)
constraints:	$1{,}000\,X_1$	$+$	$2{,}000\,X_2$	$\leq$	14,000	(site area)
	$2\,X_1$	$+$	X_2	$\leq$	16	(construction time)
	$8.10^6\,X_1$	$+$	$5.10^6\,X_2$	$\leq$	80.10^6	(budget)
			X_1	$\geq$	0	
			X_2	$\geq$	0	

The simplex algorithm (a mathematical procedure which allows an LP model to be solved with 2 or more unknown variables) can be used to find the mathematical solution. Since the example has only two unknown variables, it can be solved using a simple drawing. This can be explained simply and allows the mathematical solution to be presented graphically. The problem facing the housing association is represented in figure 318.

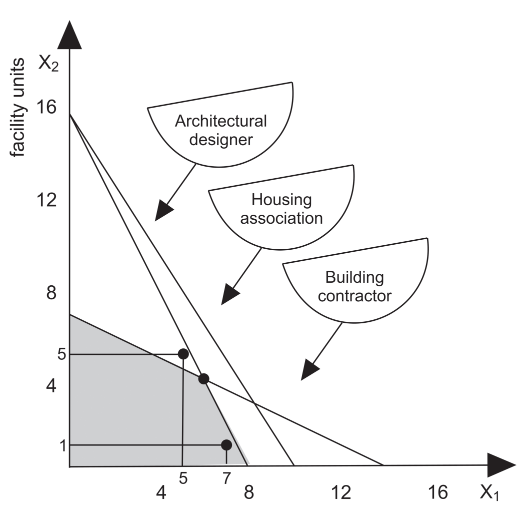
a This example is given by Berkhout and de Graaf, published in Horssen, W.T. van and A.H.P. van der Burgh (1985) *Inleiding Matrixrekening en Lineaire Optimalisering*, p. 57-59.



318 The solution space (shaded)



319 The objective function



320 Position of qualitatively optimum designs in relation to the mathematically optimum design

The maximum value of the linear equation $5X_1 + 3X_2$ (the objective function) must be found within the shaded area. Consider the group of parallel lines $5X_1 + 3X_2 = c$. The highest possible value of c has to be obtained, within the constraints. This can be achieved when $X_1 = 6$ and $X_2 = 4$, because $c = 42$. The best outcome is achieved with 6 housing blocks and 4 facility units (figure 319).

The housing association and the future residents will undoubtedly continue negotiating their decisions and goals after this 'initial' solution has been found. Such negotiation is useful in order, to establish for instance, whether a change in the construction costs might better suit preferences of the residents. Other, cheaper building materials could lower the costs, which might lead to a better distribution of houses and facilities.

32.9 THE OPTIMUM FORM INTEGRATED WITH THE OPTIMUM CHOICE

The design conception can easily be integrated with the foregoing. The first aspect of this conception - meeting the requirements the optimum way - has already been incorporated into the mathematical definition of the optimum design, since these requirements are represented in the mathematical constraints. The second aspect - optimum selection of sub-solutions - is addressed below, when the planning conception is incorporated. The third aspect - optimum quality - can be integrated as follows. The best alternative designs approved by architects as good, in terms of quality, can be divided into designs which fall within and outside the constraints of the best Pareto solution. This can even be determined unequivocally using a mathematical model. This also applies to designs which lie exactly on the point representing the mathematical optimum: the best designs. However, if there is no design at this point, a choice will have to be made from the designs within the solution space.

In the mathematical solution to the housing association's problem, the position of a design within, or outside, the solution space can be illustrated as follows (figure 320):

a. The quality plan within the solution space

If an architectural design has been made for a residential block that covers 1,400 m^2 of land and a facility unit that covers 2,500 m^2, the new optimum lies at the point $X_1 = 7.2$, $X_2 = 1.6$ (the new site area constraint: $1{,}400\ X_1 + 2{,}500\ X_2 < 14{,}000$). If the figures are rounded off, the architect is actually proposing to build 7 residential blocks and 1 facility unit.

b. The quality plan outside the solution space

If the architectural design requires 900 m^2 for a residential block and 1,800 m^2 for a facility unit, the new optimum solution lies at the point $X_1 = 5.1$, $X_2 = 5.2$ (the new site area constraint is $900\ X_1 + 1{,}500\ X_2 < 14{,}000$). In this case, 5 residential blocks and 5 facility units can be built.

Finally, the planning conception. This plays a rôle in the rational choice of alternatives falling within the constraints. The design team must agree on how to choose between these alternatives: whether to decide by vote, leave it to principal or designer, or to try to reach consensus as a team. The optimum design is the design selected according to the agreed procedure from the alternatives falling within the constraints.

Integration of all these conceptions produces the following definition of the optimum design:

The optimum design is the design selected by an explicitly defined procedure from alternatives falling within mathematically defined constraints accepted by those involved.

This definition is consistent with the Open Design viewpoint from which I looked in this Chapter at multi-actor design optimisation. After all, it includes all key features of 'multi-actor' or ‘multi-party’ negotiation and decision-making in current architectural and urban planning: the organisations involved in the design team determine each independently a part of the solution space; everyone has a say when it comes to selecting alternatives; and the organisations consult about the choices they make.

32.10 ACCEPTANCE OF AN OPEN ENDED OUTCOME

The collaboration between various designers often gets stuck. Solutions to get the ball rolling tend to be characterised by compromise rather than synthesis, as a result of the autocratic way of decision-making by a limited number of expert designers.

Some causes of this rather disappointing state of affairs:

- Combinatory explosion: there are more possibilities, opinions, alternatives than any one player can handle.
- Power games: players try to dominate.
- Unilaterally sticking to certain concepts: architects tend to nourish solutions originating from themselves rather than from others.
- Conflicts of interest: parties try to defend their own interests so vigorously that a solution for the project as a whole becomes impossible.
- Stubbornness: sticking to conventional and familiar concepts.

The process leading to an open design, i.e. a design in which the interests of all stakeholders are reflected in an optimal manner, is complex. To communicate outcomes, to gain acceptance for these outcomes, to avoid stalemate situations, to maintain momentum, etc. – the management of the entire open design process – is in practice even more crucial to success than the methods and computer tools involved.

When the interests of all designers must be incorporated in the design, no one can predict beforehand how the design will ultimately look. Since the end product is unpredictable, the management of open design must focus on process rather than content. The outcome of that process remains open-ended.