Chapter 4
Problem Formulation

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4.1 Objectives

In any problem-solving exercise, whether it is an academic research problem or a sponsored research or a problem-solving exercise to solve certain real-world problems, it is essential to know the exact nature of the problem to be solved or researched. Today, there has been a significant development in terms of novel solution methods and solution theory; the corresponding development has not taken place in terms of problem identification, problem formulation and problem structuring. To advance the science of problem-solving, we must be able to solve relevant and right problems in the efficient way. It is of no use to solve an irrelevant and wrong problem in the most efficient and elegant manner. It is therefore necessary to give adequate attention in defining and specifying the problem to be investigated in a proper scientific manner (Ackoff 1962). The present chapter is devoted to this. Thus, the objectives of the present chapter will be as follows:

- To understand the manner of classification of problems for different types of problem-solving exercises (academic research for advancement of knowledge, academic research for solving real-life problems, sponsored research, etc.)
- To appreciate various aspects of problem formulation
- To clearly understand the difference between primary and secondary problems
- To develop skills in specifying secondary problem components
- To develop capabilities for identification of various factors affecting and influencing a problem

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D.S. Hegde (ed.), *Essays on Research Methodology*,
DOI 10.1007/978-81-322-2214-9_4

- To appreciate the basic logic of modelling
- To appreciate the basic importance of good problem formulation in overall success of problem solution

4.2 Taxonomy of Problems

Any problem to be investigated may fall in any of the following classes:

(a) The research study of a problem is basically meant to explore a new area for developing concept theories or for understanding in greater depth and clarifying some existing phenomena. Many PhD, MPhil and academic studies fall under this category.
(b) Sponsored studies on some real-life problems or on some conceptual, theoretical or exploratory issues.

In all such cases, understanding the objectives which the sponsors want to achieve is very important in formulating the profile of the problem to be investigated.

(c) Solution of an existing problem within a system, society, country, organisation or environment.

Here, again understanding what exactly are causing concerns is very important before exploring solution methods.

For all the above three types of studies, understanding and specifying the problem to be studied and issues to be explored are very important, these are generally covered under the general label of '*problem formulation*'.

Thus, problem formulation consists of having a clear idea about (White 1969):

1. Who – The main person and group interested in getting the problem explored or solved.
2. What – We must be clear what the group wants to achieve through such exploration or solution.
3. How – It is also necessary in this connection to know exactly what are the alternative methods available to carry out exploration or to solve the problem.

The implications of these three things are quite different in the three classes of study that we discussed earlier. We may like to discuss each of these in respect of each class of problems.

4.3 Secondary and Primary Problems

The problem or study that we want to explore or solve is the primary problem. We also want to explore data to be collected, techniques to be applied and expertise to be employed. These are parts of the secondary problem. Good problem formulations specify both primary and secondary problems (White 1975).

In case of each type of problem class (a), (b) and (c), we shall discuss these aspects in detail.

Examples:

1. Let us assume that a candidate is doing a PhD level research and he/she wants to design an incentive scheme for the production workers. Here, he/she has the primary problem of designing an incentive scheme for the production workers. For solving the primary problems, he/she has to decide the nature of standard measures, what techniques and statistical tools to be used and what data have to be collected in these respects.
2. A chief executive of a large manufacturing organisation wanted to improve the overall effectiveness of the organisation. This is the primary problem to solve. Here, we have to define measures of organisational efficiency, find ways of measuring performance and relate such measures to resource use and with the volume and quality of output. Decisions regarding data to be collected for purposes of analysis, analytical and synthesising tools and techniques (both qualitative and quantitative) that can be used are also secondary problems.
3. In a rural development study, the idea was to design a framework of employment generation in the rural sector. This was the primary problem. The secondary problems were assessment of skills and capabilities, assessment of potential for productive economic activities, tools and techniques (both qualitative and quantitative) to be used, experts to be consulted and nature of environmental and natural resource data to be collected. These details were all components of the secondary problem.

Thus, problem formulation becomes complete when primary and secondary problems are fully and adequately specified. In doing so for primary problem, we are concerned with whom and what are specified earlier. For secondary problems, the answer to the question 'how' will be useful.

We shall now discuss each of these in the case of three classes of problems.

4.4 Problem Formulation in Academic Study

In academic study, the first issue relevant to problem formulation is the selection of the area of research that is of interest and importance and then comes the selection of a specific topic within the selected research areas/fields.

For any academic research study, the following determine the contours of selection:

(i) What areas of study are of interest to the candidate – is it also approved by the guide or selected research advisors?
(ii) Candidate's background and knowledge about the area and his/her enthusiasm and determination to explore the selected topic even when the background is not adequate initially.

(iii) Based on preliminary assessments, the candidate should be able to decide with the help of the guides and supervisors how difficult it would be to undertake the study in the proposed area. He/she should then decide (in case of background knowledge and skill gap) whether bridging the gap will be feasible without much difficulty. Thus, if a candidate's interest is in optimisation of production in steelmaking, relevant knowledge, technical and managerial, in respect of steelmaking in modern era must be adequately grasped before the study can be cracked. Candidate's existing knowledge may/may not be adequate for the purpose. In case of inadequacy, it has to be assessed how difficult it will be for the candidate to bridge the gap of managerial and technological knowledge needed for conducting the study successfully. These are also secondary decision problems. These aspects need to be resolved before selecting the right primary problem in terms of selecting an area of study and a specific area within the selected area.

(iv) In case the required expertise is not available within the institution, expertise can be made available during the period of study or it is possible to acquire the expertise in collaboration.

Thus, a candidate has selected a study area in biomedical engineering in respect of surfactant and their local production for premature born babies. The study area and topic selected required expertise and research equipment which were not available where the candidate was registered for his/her PhD work.

However, collaborative institutes were identified where required expertise and instruments were available and the candidate felt confident to use these effectively for the purpose of his/her research. He/she completed his/her experimental work in the collaborative institute.

(v) Whether data required for the research to be undertaken can be obtained easily? In certain research on say defence-related studies or organisation studies, many data may not be shared or made available. Any topic selected where such data are needed will therefore run into difficulty and therefore should not be attempted in the first place.

For selection of study area and a specific topic within, we must prejudge reasonably easy access to relevant data particularly when we are attempting time bound research studies.

(vi) Lastly, any research area and a specific topic to be taken in the area must be subject to the constraint of time available. This we have already mentioned in (v) above.

Basic criteria for selecting an academic cum research project are therefore the candidate's interest, his/her state of prior knowledge about the subject and difficulties of the subject matter in question in terms of access to new skills, new knowledge, new equipments and new sources of data.

So here again, basic ideas of the problem to be studied should not be left vague and should be adequately detailed and formulated to fix the various contours of the problem to be studied.

4.4.1 For this It Is Necessary to Classify a Research Idea/Ideas into Three Types

1. *Area*
2. *Field*
3. *Aspects*

Area is a broad field of scholarly endeavour, say economics, production engineering, system science, etc. These are all areas of research.

Field This is a component of the area representing a subdiscipline. For example, process control is a field of control engineering, macroeconomics is a field of economics, and recruitment policies are a field of human resource management.

Aspect These describe the detailed facts of a field. The use of continuous casting of steel and its effects on the level of output is an aspect of production problem study; an effect of financial incentives on the worker's productivity is also an aspect of a study of an employee's productivity. If the researcher can fix these three parameters, he/she will be able to narrow down the choice, and the task of selection of the research topic will be relatively easy. Thus, a research candidate for PhD research on incentives can specify the topic as incentive problems of manufacturing workers with special reference to financial incentive and productivity. In this case, the selected area is manufacturing; the field selected is productivity, and its relationship with incentive aspects is confined to financial incentives. Thus selected, the topic provides adequate focus.

For academic research, it is necessary to appreciate that the selection of the title of the topic should not be kept vague; it should be precise and as specific as possible.

Thus, the research topic selection should go through the following steps:

(i) Listing of possible topics and ideas
(ii) Identification of a few key attributes of the topic
(iii) Listing several topics for each of the attributes selected
(iv) Consideration of different combinations in (iii) above

In deciding the topic finally, the candidates should broadly consider for various topics selected the secondary problem areas regarding techniques and tools and methods to be used, persons to be contacted and consulted and data to be collected. All these should be within the prima facie realm of feasibility.

Comparing our framework of who, what and how with what we have discussed so far, we find in academic research, the guide and the candidate are the relevant persons who decide the problem selection, and in doing so, we have discussed the steps that should be followed.

The next question of importance would be what does the candidate intend to do and how does he/she intend to do it?

Any good academic research must display originality and generalisability having relevance beyond the situation and setting, in which the data were gathered.

Research projects identify the issues to be investigated by referring to a theory, concept or group of ideas. A research project makes its contribution by extending or adding to the existing theories, concepts and ideas in some way. Findings of good research project in applied areas like economics, sociology, management and organisation should be applicable to real-world problems. Someone somewhere should be able in principle to put the recommendation into good effect.

It may be pertinent to say that all good research projects (for PhD, MPhil, etc.) should be efficient and effective. Efficiency of a project has to do with technical possibility and feasibility.

Effectiveness on the other hand is concerned with constraints on the applicability of technically acceptable recommendations. A solution is effective if it is feasible given the various constraints.

4.5 Problem Formulation for Types (b) and (c)

We have discussed the special nature of consideration in the case of type (a) or academic research studies. We shall now discuss about the framework for sponsored, in company or consultancy, studies of real-world problems. What we discuss now on will be applicable generally for all types of problems. Wherever considered appropriate, we shall refer the methods discussed and their relevance to type (a) academic problems.

4.5.1 Who Owns the Problem?

In understanding the basic nature of a problem, it is necessary to know the decision-maker(s) who will act on the basis of recommendation after the problem/issue is resolved.

In sponsored research or in the case of consultancy problems, consultant/consultants and researchers are expected by the sponsoring agencies (of decision-maker(s)) to examine certain issues and recommend solutions for implementation. In the case of policy issues, policymakers are the owners of the problem. In organisational decision-making, the decision-maker is often known. In a sponsored project, the head of the sponsoring organisations decides the fate of the project. These are easily identifiable and do not create much difficulties, but for implementable solutions, recommendations must appreciate the viewpoints of all stakeholders. Thus, in a manufacturing organisation though the head of the organisation is the ultimate decision-maker, any recommendation that affects employees or workers adversely may be resisted, and it may become very difficult to implement the resolution.

Thus, the Industrial Development Corporation and its chief may decide a policy of industrialisation and sponsor a research study for appropriate location. In this

case, the relevant 'who' as decision-maker is the head of the state government, but if location involves dislocation of status quo at the local level like the diversion of local land from agricultural use to industrial use, the people affected must be included as part of 'who' to be considered because their opinion can affect the implementation of the ultimate optimal solution. In river valley projects, certain groups will be benefited, and certain groups will be disturbed. Both groups need to be taken as relevant section of decision-makers, and their views and interest must be given appropriate considerations while arriving at final solution to a problem.

Even in the case of academic research problems involving real-world issues, this aspect is relevant. Firstly, all groups who can influence solution and implementation must be included as relevant for seeking opinion and conducting discussion. Thus, in the case of PhD and MPhil research, the guide and the candidate can influence the research, and therefore both these groups should be in the loop. The researcher will benefit immensely by knowing what the guide wants in the ultimate analysis.

The next step in the process of problem formulation is the identification of what. What is/are being intended to be achieved through the solution of the problem? Often, the objectives are not being clearly specified. There is also confusion between constraints and objectives. In a PhD level research, the intention was to design an optimal strategy of land distribution. Here, the objectives are not clearly specified because we do not what are the criteria of optimality.

In case of a sponsored study, the sponsoring agency may suggest that the criterion of optimality is the maximisation of production, subject to the prescribed limit of unequal distribution or alternatively the policymakers may suggest that the criterion of optimality is the minimisation of skewness of the ownership of land-based assets of different sections of the farm household subject to a certain level of production being achieved from the total amount of land-based resources.

In the third place, the decision-makers may define objectives by a statement that the country wants the most egalitarian distribution of landed assets with the maximisation of production. The first two propositions are workable, but the third specification is vague because neither the statement most egalitarian nor maximisation of productions is free of ambiguity.

Similarly, the head of a railway organisation wanted minimisation of cost per passenger kilometre between station A (Glasgow) and station B (London). Of course, the least cost solution (if feasible) starts the train at Glasgow and let it stop at London without any intermediate stop. Quite clearly, this was not acceptable. The chief of the railways then specified the minimum number of stations where the train must stop and the maximum speed that may be permissible.

These examples suggest that the often concerned decision-makers are not clear about their objectives and the researcher must find out what the decision-makers want by asking relevant and appropriate questions. For example, when the policy-makers suggest that they want a land distribution which is most egalitarian, it may be pertinent to point out that such egalitarian distribution may make landholding nonviable and thereby the production may suffer; similarly, where we want to maximise production, the land distribution may become very skewed.

In actual practice, telling the top-level policymakers/lawmakers regarding infeasibilities of their statements and pronouncements may not be very much favoured. Similarly, if such statements are made by guides and advisor, the researcher faces similar dilemma. No one likes to be told that his/her statements are infeasible or illogical.

To solve this issue it is necessary to proceed in two stages. Stage one consists of defining boundaries of problem to be investigated. The problem boundary in land distribution may be the agricultural cultivable land of a specific state, district or a block. Once the boundary of the land problem is drawn, various factors outside the boundary may influence distribution. So, after drawing a problem boundary, relevant environment for the problem needs to be selected. Thus, socio-economic condition, political environment and distribution of other assets will all affect land distribution. We should identify all relevant factors that affect the strategy of land distribution and agricultural production. Similarly, all factors that affect costs of passenger per kilometre must be identified (French and Papamichail 2009).

In this connection all environmental factors that affect the internal factors identified must also be specified. In theory everything depends on everything else, and no problem-solving exercise can deal with all factors exhaustively. We will only consider those factors which have an influence on the ultimate outcome variable; the rest of the factors may be ignored.

The questions that need to be answered are what factors and variables are to be studied for the purpose of our study, how to identify them and how do we relate these variables in terms of their effects on ultimate result.

The first step in this is the identification of variables.

4.5.2 Variable Identification Method

We have to understand that in any problem, we have three types of variables: (1) uncontrolled environmental variables, (2) control variables and (3) output/input variables. Thus, in the case of land distribution, equitable distribution is an outcome variable. The amount of land allocated to a household is a control variable. These are also decision variables. Socio-economic conditions and political environment are uncontrolled variables (Bandyopadhyay 1975).

In a costing exercise of safe-deposit lockers, the idea was to decide remunerative price for lockers. Here, the ultimate price was the outcome variable, and the demand of safe locker service will determine the volume provided and will affect the cost. These are uncontrolled variables. Various inputs needed for producing safe locker service are input variable and partly controlled variables. Environmental socio-economic conditions influence demand; they are environmental variables and are not controllable.

So, for any problem to be studied, we have to identify these three types of variables.

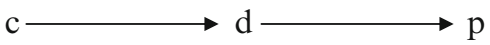

Fig. 4.1 Forward formulation (Safe deposit locker study)

These are three methods for identification of variables:

1. Forward formulation
2. Backward formulation
3. Combined backward/forward formulation

We explain and illustrate these in the next subsection.

4.5.2.1 Forward Formulation

In this type of formulation, we take our known or given concept and ask the question what other variables or factors it will influence. For example, cost of inputs will affect cost of locker service. We can ask the questions what factors of the cost of locker service will have an influence; obviously, it will influence demand – demand will influence chargeable price. This is called forward formulation.

Thus, forward formulation is obtained by starting with a variable and by repeatedly asking the question 'what will it affect?' till we reach the ultimate outcome variable or variables.

Thus, in the safe-deposit locker service case, we have the cost of input (ci) influencing the demand for locker service (d), and this will affect the chargeable price (p) – Fig. 4.1 depicts this.

Case (ii): In a maintenance study, it was necessary to determine optimal frequency of maintenance for a machine part, so that the cost of maintenance is optimal. In this case we may start with the variable frequency (f) of maintenance. Frequency will influence cost of maintenance (c); it will also influence downtime for production (dp). It will also influence the breakdown maintenance (bm) need. Breakdown maintenance need will influence production downtime and also the cost of maintenance.

Thus, Fig. 4.2 depicts this.

Both these formulations are forward formulation.

4.5.2.2 Backward Formulation

In identifying variables instead of starting with a given or known variable, we may start with the desired outcome variable and then ask the question 'what factors will influence this?' Thus, in the study of safe-deposit locker service, we are concerned with the outcome variable of chargeable price.

If we start with the variable chargeable price (pc) and ask the question which other variable will affect this, we can get the idea, socio-economic condition (SE)

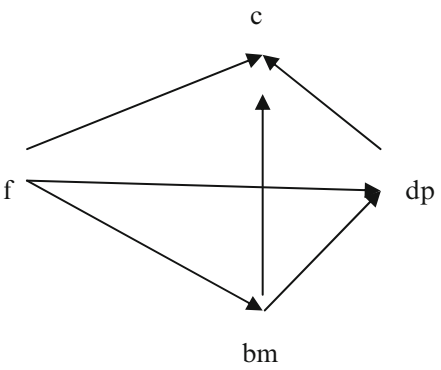

Fig. 4.2 Forward formulation (Maintenance study)

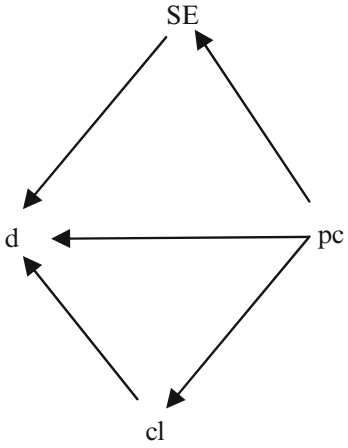

Fig. 4.3 Backward formulation (Safe deposit locker study)

of the community will affect the chargeable price, because that will affect demand (d); further chargeable price will be influenced by the cost of providing safe-deposit locker service (cl). We have the diagram of Fig. 4.3.

Here, starting from the outcome variable, we proceed backwards to identify variables by asking the question 'what influenced these factors?' The arrows show the direction from the outcome variable to the influencing variable.

4.5.2.3 Combined Backward/Forward Formulations

Here we may start with the identified variable and proceed forward and again start with the outcome variable and proceed backward. These forward/backward movements provide a network of variables.

Take the example of the inventory control problem as an illustration. In an inventory control problem, if stocks are not available to meet the demand, then we have lost sales, and there is a penalty for not having a stock. There is a cost for

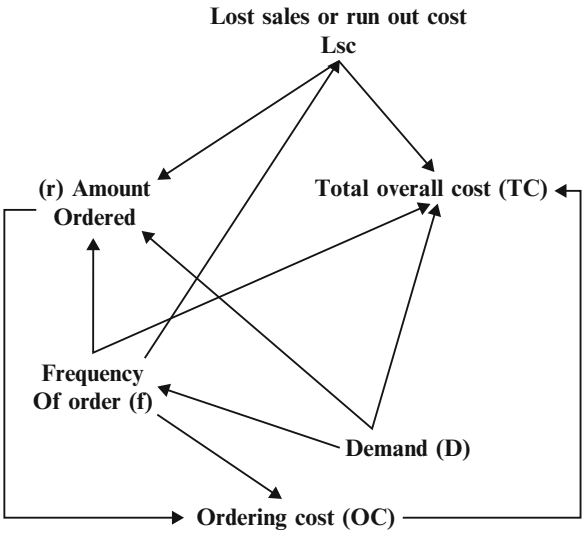

Fig. 4.4 Present the network of variables obtained through backward and forward formulation (combined) processes

ordering or for having a stock. Demand will decide the amount of order and also the frequency of order. These will determine the cost of ordering; in addition, if there is more stock than demand, there is always a stockholding cost. Thus, the overall cost is composed of runout penalty cost, stockholding cost and ordering cost. These can be identified as a network by adopting combined backward and forward formulation as shown in Fig. 4.4

In a study of energy balance in an area, the following variables were identified:

Air pollution
Biomass available
Price of kerosene
Price of diesel
Price of petrol
Price of coal
Price of wood
Industrial activities
Agricultural activities
No. of GW wells with pumps
Domestic cooking
Lightings
Transportation energy

All these can be identified as combined backward and forward formulation. Energy balance will depend on demand and supply equilibrium of energy and proceeding systematically by identifying factors affecting demand and supply and also starting from energy price and then proceeding to identify factors affected by energy price.

4.6 Clarification of 'What'

We started our discussion on determination of 'what' is intended to be achieved by the study and before completing that discussion digressed to the identification of variables. When objectives and constraints of a research study are not adequately specified, it may be pertinent first to identify relevant variables conceptually and then ask concerned people to specify which variables they want to optimise. Say in an energy balance problem related to rural developments, we identify variables like:

- Lifestyle
- Increased agricultural activities
- New industries
- Employment generation
- Migration
- Air pollution

The concerned decision-makers then identify employment generation as the main concern subject to non-deterioration of lifestyle, nonmigration and adoption of new industry subject to acceptable level of air pollution. Thus, pollution levels become constraints, employment generation becomes objective and agriculture and industry become the 'means' variable. Thus, problem is properly defined as maximisation of employment through improvement of agricultural and industrial activities so as to ensure that there is no deterioration of lifestyle and no migration takes place. Pollution is at an acceptable level, and energy balance is maintained.

Once the research problem is defined this way, we proceed to the next stage of further elaborating on available alternatives in elaborating on 'how'.

4.7 Alternatives Available and Feasible

Any problem can be resolved by following different options. The idea is to select the best option. Each option adopted will have consequences; some of them are positive and some of them will be negative. For example, the option of creating new industrial activities for generating employment by enhancing production will be increasing wealth (positive consequence). It will have negative effect in terms of creating pollution, diversion of land from agricultural use to industrial use, etc. Different options may affect different sections of the society differently. Thus, a river valley project may give irrigation facilities to certain areas, whereas it will submerge certain villages and create displacement in some other areas.

Further effects at different time periods for different options may also differ. Then, some options may give immediate beneficial and favourable results but can lead to disaster and bad long-term results. Thus, drawing of water for irrigation from groundwater by means of electric/diesel pumps may result in a better irrigation and increase agricultural production in the short term. But where the withdrawal is much

more than recharge, the process can create serious problems of groundwater quality and may force the groundwater level downward, increasing the cost of pumping up water significantly.

Any research study be it academic or sponsored if it has to have any relevance must consider all available options for solving the problem holistically considering the effects on the total system and also overtime. Only after that, we can proceed to determine the optimal.

4.8 Relations

Once variables and options are identified, it is necessary to establish relationship among variables. Unless, at least conceptually, we are able to visualise these relationships, we shall not be clear what data have to be collected. Supposing we are studying migration, we conceptually identify various factors affecting migration and also identify options available for affecting migration. We must identify how various options affect migration and in what manner. Once these things are known, we are clear what data should be collected and how these data should be analysed. Thus, for solving any problem, real-life issues have to be depicted in our research proposal either through description or through some modelling. Thus for every research study, modelling is essential.

4.9 Representation of the Problem Reality

Modelling is nothing but representation of reality. It is not reality but it gives a picture of reality. We have an esoteric view of a model. 'All models must be mathematical'; thus, the statement is not at all true; on the other hand, no good research is possible without a picture or description of what is to be done, how it is to be done and for whose benefit it is to be done. This is what modelling is for.

Thus in any research study, we must know the present state; we must specify the desired state to be obtained through study, options available to us and various factors that will influence the result. Some of these variables or factors are under our control for which we will take the appropriate actions. Some variables and factors are not within our control; these are called uncontrolled and free environmental variables. These variables can be anticipated and projected. So, forecasting of free environmental variables is needed.

Thus, following 'White' (White 1975), we can draw a simplified diagram for research problem modelling (Fig. 4.5).

Any research is based on certain basic assumptions and measures adopted for the particular study; by varying the assumptions, relations and measures, we can generate different solutions. Of course, any research has limitations regarding time and resources. Within those limits various solutions can be generated, and effects can be assessed.

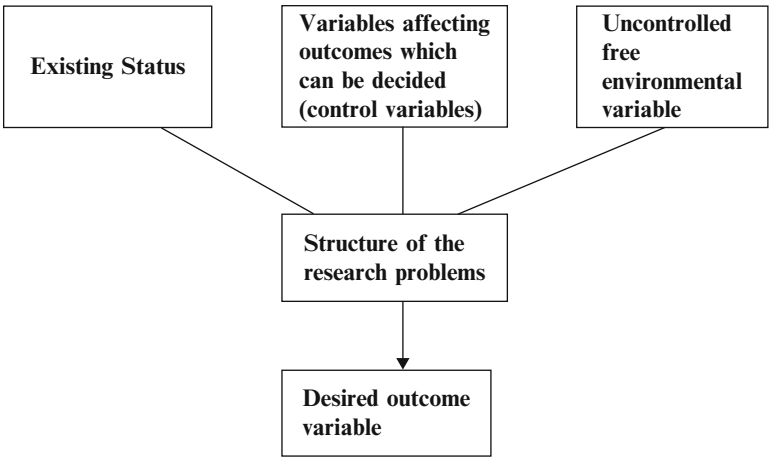

Fig. 4.5 Model of research problems

4.10 Benefits of Problem Formulation

Thus, problem formulation consists of (Ackoff 1981):

1. Identification of decision-makers
2. Identification of objectives and constraints
3. Identification of alternatives
4. Establishing of relationships outcome
5. Formulation of total framework for representing reality

Once problems are structured this way (Rosenhead 1996), the data requirements for the study become clear. Quite often data demands are excessive, and access to data is difficult. Problem to be studied may be modified both in nature and scope to suit data availability. Even for academic research, these steps are very essential. It relieves much trouble later on. It is advisable that for every problem researched, the problem should be properly specified by following logical scientific processes and methods. We have demonstrated these methods. We shall explain the methods in details by means of a few case studies.

4.11 A Few Case Examples

4.11.1 Case A

A PhD level, the thesis title was 'Evolving Sustainable Urban Transportation for India'. The topic as a presentation is not very explicit about the range of analysis, factors to be dealt with and other related aspects. To write a comprehensive proposal based on scientific problem formulation, we may precede as follows. As for our

earlier discussed framework of academic research, at present, research area is multidisciplinary – it encompasses the disciplines of economics, civil engineering, energy engineering and environmental science. Field within these disciplines is transportation and urbanisation and other related technologies. Aspects to be dealt with are pollution levels and satisfactory urban transport system in India (for intercity and intracity transportation).

The next question to be satisfactorily answered is to identify the ownership of this problem. Obviously, PhD guide and PhD advisory committees expect some results out of the research study which will extend the frontiers of knowledge, but to be relevant, the study should produce outcomes that can influence policy related to urban transport planning and sustainability. Thus, policymakers and community as a whole are interested in the project outcome. What exactly is expected is difficult to decide, but quite clearly broadly speaking, most of the groups identified above would like to have a clear idea of a profile urban transportation that will be efficient, effective and sustainable. If these are the objectives we have in mind, how should we proceed to structure the problem further. As it is to sketch, the urban transportation profile for the country as a whole is a gigantic problem, so we need to specify the exact boundaries of the problem. The overall transport framework, intercity and intracity, transportation and intermodal character (road, railways, air and water) are to be tackled. Both goods and passenger traffic have to be handled. However, apart from the broad framework, no detailed statewise or districtwise or areawise framework development may be feasible.

Thus, the problem boundary can be defined as India and its broad transport system for urban areas. The next stage will be the identification of various factors and variables relevant to the resolution of the research study.

Here, we must specify alternatives and their effects. We are to identify consequence variables for alternative transport profiles. These consequence variables can be identified by the forward or backward formulation or by combined backward/forward formulation. Thus, we can take ultimate consequence of speedy urban travel and then ask the question, 'which will affect the speed?' Another ultimate consequence may be congestion and also the degree of pollution, and we then ask the question 'what factors will affect congestion and pollution?' So, we can identify factors like volume of traffic, technology, technology of travel, mode of travel energy use pattern, energy use efficiency, width of road, frequency of public transport, number of vehicles in use and their polluting effects. Demand of transportation will be influenced by the location of economic activities and centralisation and decentralisation of such activities. Sustainability as a consequence variable will depend on available sources of energy, efficiency of energy conversion, capacity utilisation of vehicles and efforts for demand management.

We can also start with existing alternatives in urban transportation, how these will be influenced in the future and identify various factors till we reach the ultimate consequence variables. Thus, continuing with these processes, we may be able to identify the following variables (neither illustrative nor exhaustive):

Consequence variables: Congestion, speed, accident, cost, energy consumption and pollution infrastructure profile for various transportation modes

Intermediate variable: Public-private partnership for urban transport infrastructure, administrative system, capacity utilisation, traffic control, pollution control arrangement, location of economic activities, etc.

Decision variable: Intermodal mix,
selection of technologies and energy use levels,
methods of demand management and capacity utilisation,
selection of mode of public transport,
relocation of activities and
creation of infrastructure

Once most critical variables are identified, we can then identify the data requirement. Here in this case, we should get data regarding technological modernisation and options available in different transportation modes and their relative costs and advantages. Energy source, data affecting demand for transportation, growth of economy (GDP), scale of urbanisation and trend of migration from rural hinterland to rural areas. Polluting effects of each type of vehicles and transport modes, total effects on demand on available energy sources and data of various energy resources available.

In addition, we may like to have data regarding global trends in urbanisation and urban transportation. Special stress may be given to data regarding evolution of urban transportation of developing economies like Brazil and China. For sustainability assessment, we must obtain data on polluting effects of various alternatives and data regarding means available for reducing congestion, pollution and causing better capacity utilisation (so we should have data about urban infrastructure for present and projected future needs and present level of capacity utilisation). Effects of public transport and creating vehicle free zones – not encouraging private transportation in certain areas – may be studied. We should then have data in respect of these aspects.

Broadly speaking Indian urban transport will be partly influenced by global trends of urban transport. Thus we can draw a broad conceptual model of the problem (Fig. 4.6).

Once this broad conceptual framework is developed, w can then see that there are various aspects that we are ignoring, for example, with the growth of demand, more volume of traffic will emerge; with the dominance of private transport, the demand on transport infrastructure will grow; the requirement of land for broadening of road network may create diversion of agricultural land and create non-sustainability. Sustainability has to be therefore assessed in respect of all non-renewable resources. We may deliberately avoid certain factors to tackle a problem that is manageable. Thus we may assume that social tension arising out of diversion of land will not be a part of our study.

When the problem is formulated this way, we can write a proposal defining the primary problem of urban transportation and second problem of understanding transport technology and choice between private and public transport. Secondary problem will also be the determination of effects on sustainability of different transport options – secondary problem will also be the location of economic activities, strategies of rural development and their effects on rural-urban migration, degree of urbanisation and demand for urban transportation. We should try to

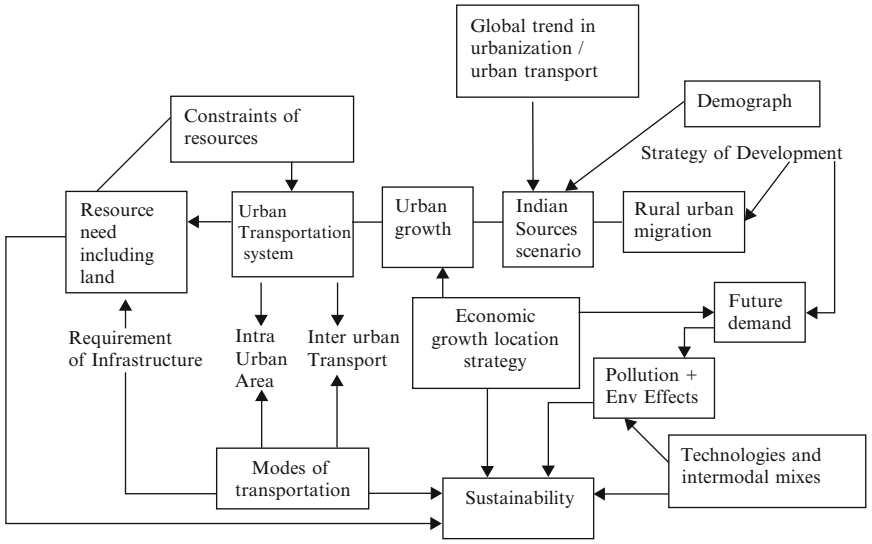

Fig. 4.6 Models of urban transportation. Major components to be studied

specify all important secondary problems to understand clearly the range of expertise, skill and data required to successfully tackle the primary problem. If necessary we can suitably modify the specification of the primary problem based on our details of problems of formulation, identification of variables, constraints and various secondary problems.

4.11.2 Case B

There was a sponsored problem to be resolved. Sponsoring agency was the Department of Science and Technology/Government of India. The sponsoring agency was working on behalf of the 'Pulse Mission'. The project was entitled as pulse production strategy for making the country self-sufficient in pulse within the next 10 years, so that dependency on export is brought down to nil.

The primary problem was to increase production of pulse to meet the total demand of pulses in the economy. Here, the owner of the problem was early identified – it was the Pulse Production Mission set up by the Government of India. 'What' are the objectives of the owners are also very clear. The objectives are improving the total production of pulse within the next 10 years so that the total pulse produced in the economy is sufficient to meet the total demand for pulses. However, such specification of objectives is not complete. We must know the constraints involved in the solution of the problem. The amount of land that can be allocated to pulse production was limited. People's preferences of different types of pulses and effects of such choices on production decision of farmers have to be considered. Thus after properly specifying constraints and objectives, we wanted

to identify various factors affecting pulse production. Here, we can use combined forward and backward formulation described earlier in this section. On the basis of such method, we identified the following variables.

Different type of pulses
Demand of different pulses
Costs of production
Productivity
Land allocated for pulse production
Land needed for self sufficiency
Technology of pulse production

These basic concepts can be used to generate further important variables for solving the problem. Thus the cost of production will depend on technology, seeds, water requirement, labour and farm management practices. Existing land for cereal production cannot possibly be diverted to pulse production, because that will affect cereal production. So there is a constraint of pulse production in terms of land available that are dedicated only for pulse products. Intercropping may release the constraint to some extents. Thus 'intercropping' becomes another important concept.

For each of the above concepts, there are constraints and boundaries.

These constraints are being adhered to. Secondary problem identification consisted of the identification of technologies available for production, estimation of demand for pulses and estimation of productivity. Having identified the basic objectives, constraints and available options for improvement of productivity and related cost, we can formulate a conceptual model of the problem (Fig. 4.7).

Here, free environmental variables were population growth and their pattern of pulse consumption. These are uncertain environmental variables and have to be projected on the basis of past data and trends.

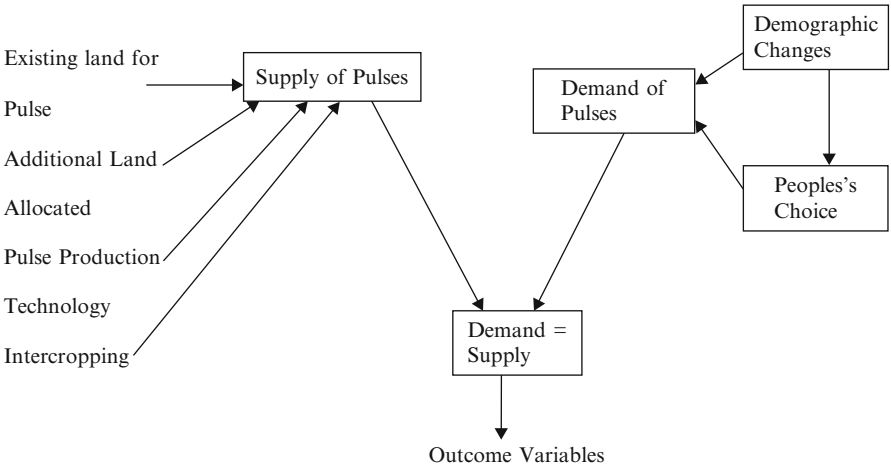

Fig. 4.7 Model for optimising pulse production

Existing situation of land devoted to pulse production and available technologies are state variables.

Once these aspects are identified, data requirements for the project can be easily specified.

4.11.3 Case C

In this case, it was needed to assess the impact on pollution of chemical industry with special reference to chemical industry in Gujarat. This problem is a better specified problem. It deals with areas of chemical engineering and environmental science. It specifically deals with chemical industries in Gujarat. The owners of the problem (which was a PhD level problem) were of course the guide and research advisors, but the results will be used for policy formulation at state and national levels, so their views should be taken, in considering ownership of problem.

The objective of the research is to assess the impact of various chemical production technologies in creating pollution in the environment – thus the objective is to objectively assess environmental impact of various chemical manufacturing

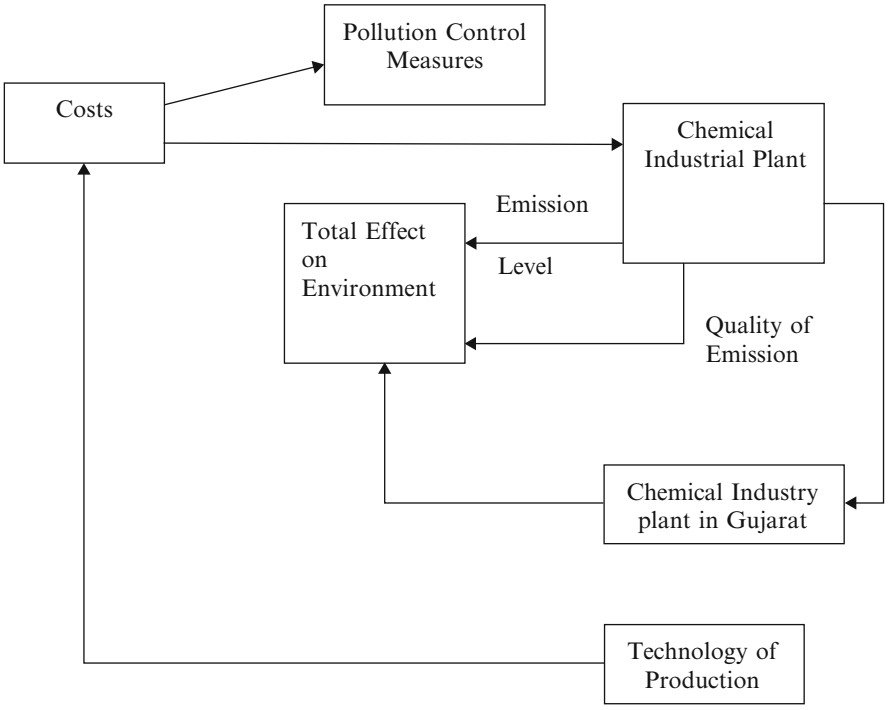

Fig. 4.8 Model of polluting chemical industry

plants and also specifically to asses such impact in the case of industry in Gujarat. Relevant variable can be identified by following forward and backward formulation. The pollution levels are affected by emitted gases and their compositions. The pollution levels also depend on pollution control measures taken by various chemical manufacturing units in Gujarat (Fig. 4.8).

The above figure defines the various components of the proposed research study. It provides guidance regarding data requirements for the study of pollution of chemical industry in general and in Gujarat in particular.

We have discussed three cases of which we have discussed two cases in detail.

It may be stressed that whatever may be the nature of the research problem, some attention initially in formulating the problem scientifically always helps. It helps in working the research proposal, planning the study and also in data collection.

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