Development Of Manpower System For Enhancement Of Industrial Output Using Mathematical Programming Model

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Abstract: The study dwelt on the problem of developing manpower supply for establishing new industries, more especially, an engineering program for generating the skills required for a refinery project. A mathematical programming model was_developed for planning the establishment of a new manpower system such as Nigeria would be establishing in the next several decades. The manpower planning model developed here deals with the problem of how to optimize the process of developing new skills so that they are available as needed during the process of setting up new industries especially in the sector of developing economy. Many developmental projects in the public sector of Nigeria are now leveled up for lack of trained manpower. The method developed, will also estimate the probable availability of skills required and plan to meet the shortfalls if any.

Index Terms: Manpower system, demand target, estimate of skill requirement, development of new skills, mathematical programming model.

1.0 INTRODUCTION

The application of mathematical techniques to the problem of manpower planning is relatively new. The impetus for this development is derived from the increasing awareness that the efficient development and deployment of skills is probably the most important factor that accelerates corporate or national growth. In most developing countries, people are taken for granted. This is a mistake, talented persons are scarce in any society, hence to develop and make most effective use of the few should be one of the most important of any nation's objectives. The spectacle of highly trained persons languishing in dreary routine jobs or even wasting in unemployment should be considered a national catastrophe The intention here is to develop a manpower planning methodology, especially for industrial skills, which explicitly relates manpower supply to manpower demands targets overtime. But before that, it is desirable to explain the phrase "manpower system". It is also desirable to indicate the aims and nature of mathematical model in relation to a manpower system for the information of possible users of these models in Nigeria where these techniques are just beginning to be appreciated.

2.0 LITERATURE REVIEW

What is manpower system?

All human activities of any major scale are operated by individual or group of individuals performing assigned role in the pursuit of the goals of an enterprise, there are many other factors which hinder or promote productive interaction between members of any working group in an enterprise. Some of such factors are recruitment, retirements, pay, promotion and other general conditions of services. Some of these factors are inputs, outputs, or changes within the enterprise.

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In the course of time changes in policy or practice effecting any one factor, could affect some or all of the other factors which may in turn generate reverberations throughout the enterprise. A manpower system is therefore, any collection of individuals employed for some common purposes in which some or all of the above interactions occur. Most of the factors indicated are interdependent and improper handling of any one of them could create conditions that could halt the effective operation of an enterprise. It is therefore, apparent that merely planning the effective production of skills is insufficient if they are not productively used through efficient manpower management.

Aims of the mathematical model

A manpower system for a large enterprise such as petroleum refining plant is a complex system. Some of the important factors that influence human behavior are psychological; mathematics can hardly teach the needs for good human relations. What it can do is to quantify certain factors in a manpower system such that they can be made available for objective study in the hope that they might generate greater insight to help attain efficient manpower management. It is fortunate that in the past two or three decades, certain mathematical techniques which turn out to be potentially useful for the study of manpower systems is still fairly new and there is yet inadequate practical experience to say how widely applicable or effective the models are. What seems certain is that it is possible to bend these earlier theories to the new purpose of the quantitative study of manpower systems

3.0 METHODOLOGY

The manpower developed here considers the division of grades of salary or any other defined characteristics of group of individuals, age, and seniority or of level of competitive skills. There are horizontal divisions between the grades such that those at the higher levels are more senior than those at lower levels. Vertical division denotes differences in function or specializations. Internal transfer within the system either vertical or horizontally will normally be possible. Considering the system as a whole, there will be flows into it consisting of recruits of new staff and flows out of it consisting of those who leave for various reasons. The foregoing description if spiced with the observation that the flows between grades or in and out of the system have element of uncertainty about them, one is immediately reminded of dynamic probabilistic systems based on markov's probability theory. There are several reasons why one would want to develop a quantitative representation of a manpower system. Changes occur in an established manpower system overtime and one would want to predict future behavior of the system in the light of the past performance or present indications. It may be desirable to know how many men are left in a certain grade three years hence or in respect of the training program, how many men will acquire certain type of skills in that time. A mathematical model could help management to control the system. Control is used in the neutral sense to cover all those changes subject to discretion of management. Some instances are: increase in recruitment numbers, changes in promotion rates and the expansion or contraction of certain grades. In general term, the quantitative study of manpower system is to bring some science into manpower planning and management which have very often proceeded by the hunch or the intuition of a manager or government official who sits at his desk and contemplates the system It is hoped that a mathematical representation of some aspect of the system which is of interest would create a blue print for amassing the kind of data which are necessary for effective manpower planning. The building of model is an art which like all arts, is perfected through assiduous practice. Quite often in the process of model-building, one starts with a structural representation of the system which a mathematical model is sought. One then attempt to characterize the various aspect of the structure with mathematical concept that best approximate to the physical reality which the structure is intended to represent. To make the model tractable, one makes simplifying assumption and discards all but essential features of the system. In what follows, an attempt will be made to develop a manpower planning model from the insights gained through study of petroleum refining industry. I want to develop a model for planning the supply of skilled persons in phase with the establishment of new industrial projects. It is hoped that such a model would help to reduce the incidence of delays in project implementation due to inadequate supply of trained persons.

4.0 A MODEL FOR PLANNING MANPOWER SUPPLY IN RELATION TO MANPOWER TARGETS

Over a plan period it is desired to set up an industry or a group of industries and it is required that adequate manpower supply should be available to man the projects as they are established. It is assumed that the projects have been identified and that on the basis of either economic evaluation or some criteria of desirability, they have been ranked according to some priority rating. The projects are assumed to be ready for implementation program as plants of the oil refining project. Over a plan period, there will be manpower demand targets $B(\theta, t)$ – a large vector of skills, it is desired that the manpower supply should supply the demand vectors at each point in time from the various sources to be identified. There are two main sources of skilled manpower; citizens of the country and expatriate. A developing nation would naturally prefer to staff its industries with its citizens because of skill expertise and experience. Hence, at the early stages of industrial development, any planning model must take account of the possibility of employing expatriates. In order to facilitate analysis, it is desirable to distinguish the following categories of persons from the two main sources.

(i) Experience indigenous specialists
(ii) Experienced expatriate specialists
(iii) Indigenous persons with technical education
(iv) Indigenous persons with appropriate basic education but with no technical education

It is necessary to briefly comment on these categories.

i. Clearly any manpower planner would want to count on as many of those in this category as possible to fill the expected need in new industries. The number in this category is necessarily very limited in many technical skills. There is also the further problem of "robbing Peter – to – pay – Paul" whenever one recruits skilled persons from an established enterprise in order to start a new one. The population vector representing different skills in this category at any point in time could have very small or zero elements for some skills.
ii. Expatriates: Since one could recruit expatriates from many countries, it is always possible if one is willing to pay the price to recruit expatriate for various projects. Competent expatriates are expensive and a planner would only want to use them whenever technical expertise and levels of experience are high.
iii. Indigenous persons with basic technical education but with inadequate or no industrial experience: This is a very important group in a situation such as Nigeria where there are well – established institutions for technical education.
iv. Indigenous persons with only basic education constitute the largest group but a planner is severely handicapped for short term manpower supply because of the time lag necessary to provide technical education and industrial experience. To educate an engineer in a university takes four to five years depending on the level of basic education with which he starts. A technician with basic secondary education would require two to four years to complete his technical education. The craft skill trainee with suitable prevocational education would require two to three years to acquire his initial skill training in a technical training school.

After the basic technical education, they all have to undertake a further period of practical training in industry before they can be reliably assigned to production jobs. If one is planning the manpower supply for a specific industry, one should not always count on the availability of persons sent to acquire general technical education because they could take their acquired diploma elsewhere to work before they are initiated into the specific skills of the industry for which they were originally earmarked. It is, therefore, obvious that this group is not an assured source for short-range manpower supply for rapid establishment of industries. However, if the planning horizon is up to ten years as assumed for the petroleum refining plant, it is feasible to consider this group but the certainty regarding their ultimate availability is undiminished. Figure 4-1 depicts the foregoing categorization in relation to the education system and skill formation for the refinery industry in Nigeria. The next step is to abstract a quantitative representation of the system and attempt to optimize the process of generating skills through it. It should be noted that at the planning stage we are concerned with determining the types and numbers of skills required and to ensure that they would be available when needed. The previous chapters described in great detail the process of quantifying the required types of skills for the proposed petroleum refining plant. Tables 4-1 to 4-3 gave the numbers and types of skills required over a plan period for the refining plant determined according to phased construction and commissioning program. This is recommended prototype for establishing new industries. A similar effort must be made for any new industrial project to be implemented over a plan period. Previous work on manpower phasing gave numbers and types of skills. Now, assuming that the types and quantities of skills have been determined and distributed according to some project implementation program; how is it to be ensured that they will be made available as needed? Is there some way of optimizing the process of doing this? To attempt an answer to these questions is the essence of what follows. Figure 4-2 is an abstract and concise structural model of the manpower system for the Nigerian oil industry represented by figure 4-1. The top boxes represent the major sources as categorized in the previous sections. It is seen that all supplies for main sources converge to the induction box. The task is to ensure that adequate skilled persons for this project can be generated through the system so as to meet each demand vector B(θ, t) over the entire plan period. In order to show more detailed analysis, we desegregate the compact form of Figure 4-2 into more detailed representation in Fig 4-3. The major sources are shown in Figure 4-3 as follows: Q_{IT} (t-t) = the population vector at time (t-t) where t is the output time for any skill which started technical education t-time previously to acquire the required skill with average level of experience θ. For the purpose of technical manpower development for crude oil refining, this source is further desegregated into three main sources as shown γ = duration of period of industrial training. This includes any period of probation or apprenticeship before a person is declared capable of working independently with average experienced worker standard of θ. θ = average experienced worker standard in years. It is taken to mean that level of θ experience required of every person in a given skill, be him a manager or a craftsman, in order to give average performance in his post. It is a very important quantity in the model being developed. It has to be specified for every skill in the manpower target vector B(θ ,t) for all t. **Q_E (.)** = the population vector of expatriates at any time (.), it is assumed that all expatriates have to be competent with the appropriate level of experience when engaged. **Q_{IP} (.)** = the population of indigenous persons with technical education but lacking industrial experience. When recruited, they will go through the process of industrial training at home or abroad in order to acquire the appropriate level of experience before assignment to independent working status on a job. **Q_I (.)** = the population of indigenous persons with appropriate level of experience at time (.), Persons in this group are either employed at any time or are in the process of changing jobs. They can be recruited for direct Appointment to jobs at any time t as shown in the figure. Now in Figure 4-3, there are various channels (shown in full lines) through which a person can transit from a given source to a given skill. For instance, an individual with a minimum of nine years of schooling can become a millwright through various channels. He can go through a technical training school to first train as a fitter/machinist. At the end of say three years, he comes out of the technical education system with his basic craft certificate. He can then be sent to a plant in Nigeria, say Nigerian railways workshop at Ebute Metta Lagos for eight years as an apprentice millwright. At the end of the period, he is expected to have attained the level of experience θ for a millwright at which point he can take up a job at time t to satisfy one element of the millwright component of B(θ ,t) in the industry. In general, the fitter/machinist emerging from any technical training school could be sent to any industrial plant to acquire the skills of a millwright. The same process applies to an engineer or a technician. Any person from any source in Q_{IT} (.) has to complete his overall training in (λ+γ) years before he takes up an appropriate job in a given slot of B(θ,t**)** Looking at the previous thesis, the study has proved that Nigeria has more mechanical engineers than others engineers, therefore to illustrate further, a mechanical engineer could be converted to a metallurgical engineer through a channel which starts from the appropriate source in Q_{IT} (.). The person started as a mechanical engineer by spending λ years in the university to obtain his degree. He now goes through a process of theoretical orientation and industrial experience to make him a metallurgical engineer with extended λ years of training which is more than that normally required for a normal metallurgist. In principle, it should be possible to go from any source through any number of channels in order to attain some skill in B(θ, t). But the more devious the process, the more costly it would be. It is apparent that sources and channels have capacity limitations or constraints. Technical education institutions have limited capacities for students in any chosen course. Similarly, industrial plants have limited capacities for training in any selected skill. Any randomly chosen channel from some source to a given skill has a cost, a transition probability and a transition time associated with it. A good channel could have low capacity, high cost and high transition probability for a given skill. We define the following quantities. $\boldsymbol{C^{i}_{sp}}$ **(.)** = the cost associated with the transition from source s, through channel **ρ** to attain the level of experience θi for skill i.

ρ = 1,2,........., m for each source s.

τ = the transition time

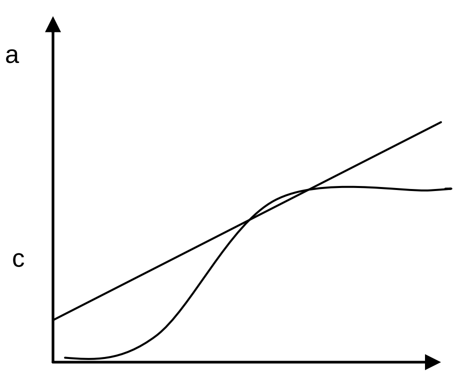
= θ if s $\in Q_1$ (.) or Q_E (.)

= γ if s $\in Q_{IP}$ (.)

= ($\lambda + \gamma$) if s $\in Q_{IT}$ (.)

$\mathbf{a^{i}_{sp}}$ **(.)** = the transition probability from source s, through channel **ρ** to θ for skill i.
i = 1, 2, ..., n.
$\boldsymbol{x^{i}_{sp}}$ **(.)** = the decision variable.

There is a direct relationship between the cost c and the transition probability a. In the case of training from a source in Q_{IT}(.), c includes the cost of institutional fees through (λ + γ) together with salaries or any allowances that may be paid to trainees. Thus, expensive institutions which offer good training programs could have a high a. One would ordinarily expect a poor institution to have low a. It should be noted that the aim is not to merely pass the training program but to attain a certain level of skill previously specified. If the source in Q_E, Q_{IP} or Q_1, the cost includes the salaries and all incentives, the cost of recruitment (e.g., advertisements and interviews). The higher the overall incentives offered, the greater the overall intensity of the recruitment effort, the greater will be the probability of obtaining the required skill from a given source. Thus, it is conceivable that as c increases, a will increase until it tapers off as shown below. If we have all the curves drawn for each i, each source s, channel ρ and transition time τ, we would choose the c that gives the highest a as the operating point for a given set of parameters. Unfortunately, we cannot plot curves very readily because any plan made is for the future and past data are of very little use in this regard, especially in these days of inflation. Therefore, we just estimates a for any selected cost for a given set of the parameters i, s, ρ and τ.



For a source in Q_{IT} (.), the transition probability can be partly calculated and partly estimated. For the calculation part, we define one step transition matrices P(λ) and P(γ) respectively for the process of going through λ period of technical education and γ period of industrial training. The (λ +1) λ^{+1} step transition matrix is given by [p (λ)] λ^{+1} and similarly for (γ +1) step transition matrix. These matrices could be different for each course in any given institution. The P(λ) can be calculated from past institution records for each course. The P(γ) matrix may not be well defined because the process of industrial training may not be well structured into definite transition steps as for an educational institution. The overall a^{i}_{sp} (.) is the product of appropriate elements of [p(λ)] λ^{+1} and [p(γ)] λ^{+1}. Now the "a" obtained so far does not in general allow for the quality of the institutions or of the course offered. Hence, we have to further encode the quality of the overall program into a in some subjective manner. One assumes that this can be done without going into the controversies of "objectives" vs. "subjective" probability assessments. It is basic assumption of the structure shown in figure 4-3 that all B(θ, t) is to be permanently filled by indigenous persons after they have attained the appropriate level of experience in a given skill. Expatriates will be assigned well-defined roles as purveyors of expertise at cost. That is to say, expatriates will play the role of channels for training indigenous persons to acquire necessary skills for the refinery. Thus, expatriates can be recruited into technical education institutions as teachers or as experienced specialists in industrial plants where they should have indigenous understudies. For instance, in the case of the petroleum refining project, the technical partners will provide a team of experts to design, erect commission and initially operate the plant. It is a basic requirement of my model that every single expatriate for this project should have an indigenous understudy. The manpower supply should be planned to ensure that at least one understudy is available to each expatriate. If it is estimated that the average probability of attaining competence in a certain job initially occupied by an expatriate is half, then there should be two understudies. In figure 4-3, Q_E (.) is in two parts Q_E [(t-($\lambda + \gamma$)] and Q_E (t-γ). Expatriate teachers should be recruited into technical education institutions at time [t-($\lambda + \gamma$)] and into the refining plants at time (t- γ) so as to provide suitable channels for persons in Q_{IT} (t-τ) and Q_{IP} (t- γ) respectively. We complete the specification of the model by defining source capacity as K_s (.) and channel capacity as K_ρ (.). The source capacities are clear for the population Q_{IT} (.). Each group of graduates from a specified course in a technical education institution is a source Q_{IP} (.). Similarly, the source Q_I (.) is made up of various groups of experienced indigenous specialists in specified skills for the refining plants. The channel capacities determine admission limits for course either in institutions or plants. Thus, for a given channel starting from a source in Q_{IT} (.) to provide a given skill in B(θ, t), the constraint could be either in the technical education institution or in the industrial plant. Having carefully defined all these variables, we are now in a position to formulate the optimization problem of ensuring that the flow of persons through the structural model shown in Figure 4-3 shall satisfy the manpower demand targets for the proposed refining plant in Nigeria. The problem is to ensure that the manpower supply shall satisfy the manpower targets at minimum cost. This may be formulated as a linear programming optimization problem. We want to minimize the total cost over a chosen plan period for supplying various skills subject to demand, source and channel capacity constraints. Hence, we have:

Minimize $\sum\sum\sum\sum c^{i}_{sp}(t-\tau)\, x^{j}_{sp}(t-\tau)$

$i\ \ s\ \ p\ \ t$

Such that

$\sum\sum a^{i}_{sp}(t-\tau)\, x^{j}_{sp}(t-\tau) \geq B^{I}((\theta, t)$

$s\ \ p$

$\sum\sum x^{j}_{sp}(t-\tau) \leq Ks(t-\tau))$

$s\ \ p$

$\sum\sum x^{j}_{sp}(t-\tau) \leq Kp(\delta)$

$s\ \ i$

Where δ is the bottleneck time. It is equal to t-τ if the bottleneck is at the technical education institutions and t-γ if the bottleneck is at the industrial plants. t is of course, the output time.

And $(t-\tau) \geq 0$ since we cannot deal with the past $\tau = (\lambda + \gamma)$ for $s \in Q_{IT}(t-\tau)$

$= \gamma$ for $s \in Q_{IP}(t-\gamma)$ $= \theta$ for $s \in Q_1(t)$

5.0 APPLICATION

This is a large linear programming problem which could have several thousand variables depending on the number of skills, the length of the planning horizon, the number of sources and channels. In the case of the petroleum refining industry, the demand vector B(θ,t) has about 55 skills. Thus, if we assume that each B^{i} (θ, t) is satisfied through two sources and channels for each year of a ten-year period for this project, the number of variables is of the order of 4x55x10, i.e., 2200. If the number of channels ρ is large, the total number of variables could be very large for a long planning horizon. It is clear that even with a modest number of variables and constraint inequalities, the problem can only be solved with a high speed and high capacity computer. The solution to the problem would yield important information for planning manpower supply for the project. At each point in time we would know what action we need to take in order to meet our manpower targets. The solution or lack of solution would give information as to where troublesome bottlenecks are located. It is always possible to create additional channels using expatriate from many countries. The Lagrange multipliers from the primal engineering problem or the solution of the dual problem will provide information to the cost of increasing the manpower demand targets, increasing the manpower demand targets, increasing the source and channel capacities. We have to make all sorts of sensitivity analyses on the cost estimates, the probability estimates and the demand constraints to obtain very useful planning information. It is therefore, apparent that the foregoing formulation could be a very valuable planning tool if we have a computer to make the necessary computation, assuming, of course, that appropriate data are available. Here it is necessary to draw attention to the last sentence in section 4.1; namely it is hope that engineering mathematical representation of some aspect of the system developed here which is of interest to this study, would create a blue print for amassing the kind of data which are necessary for effective manpower planning" for crude oil refining plant in Nigeria. While it is often true that one cannot develop method of analyzing a practical problem without data,. From the foregoing formulation, the kind of data that needs to be collected is clear from the definition of various quantities.

6.0 CONCLUSION

The problem of manpower supply to satisfy manpower demand targets has been formulated as an optimization problem subject to constraints. The methodology can be used for a single large project or several. For a single large project such as petroleum refining plant, its claim to the total pool of manpower supply will be in competition with other industries or sectors of the entire economy. From the model it is clear that each skill required at each point in time, the quantity B (θ,t) is to be variant, that is to say that the number B(θ,t) must be supplied subject to the sources and channels can be used to fill the skill demand B(θ,t) for any time t over the planning horizon T. Further study on this will use the model established to evaluate the optimal cost in the above sub problems The cost for the supply of manpower required from sources and channels, cost for under-manning and over-manning, unit cost for training personnel, forecasting output of educational institutions, resolving conflicting manpower claims from projects The model will equally serve as awareness to would be managers for effective management of a new manpower system in order to avoid many pitfalls that may occur in complex industrial manpower system in any developing country like Nigeria.

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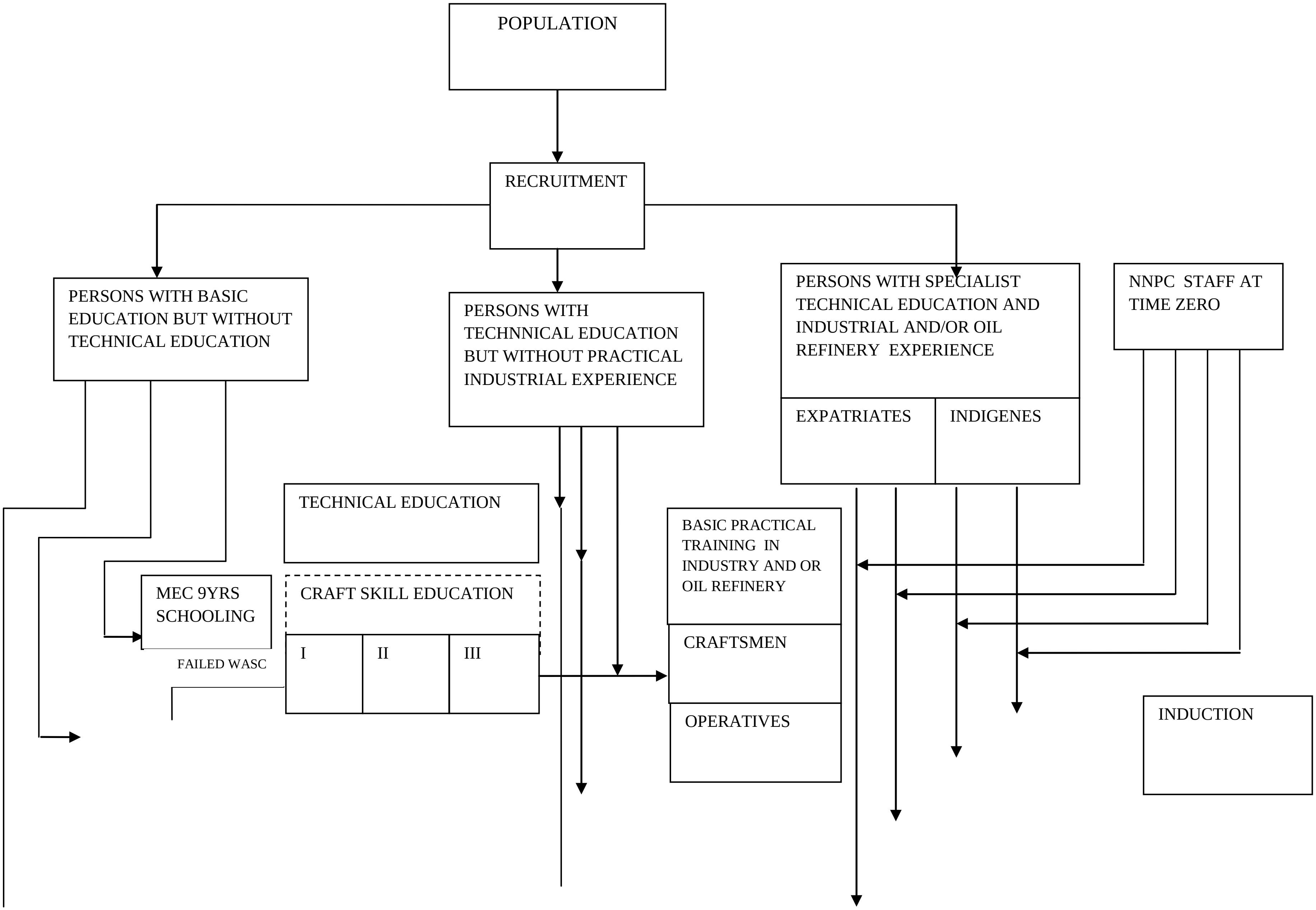
A MODEL FOR PLANNING MANPOWER SUPPLY IN RELATION TO MANPOWER TARGETS



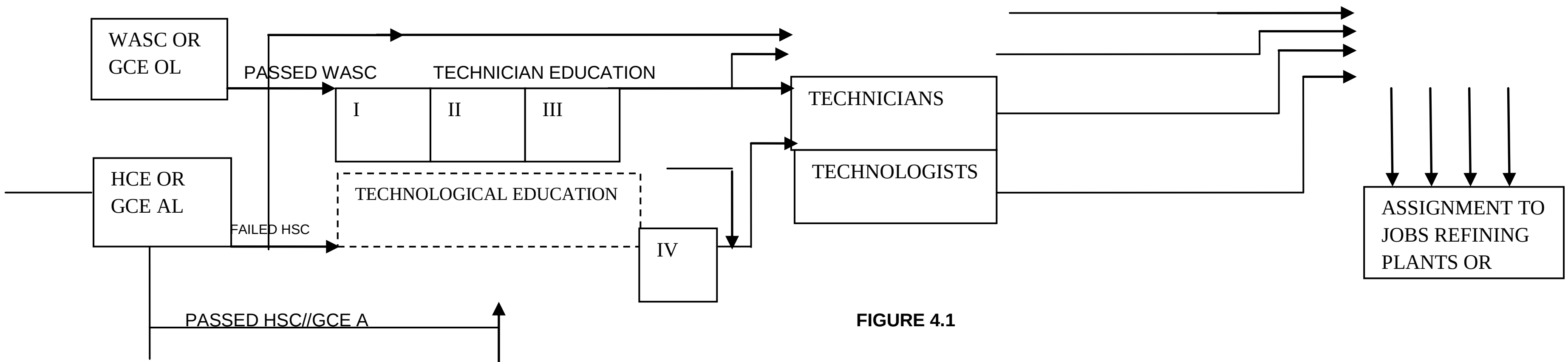


FIGURE 4.1

λ = duration of period of technical education

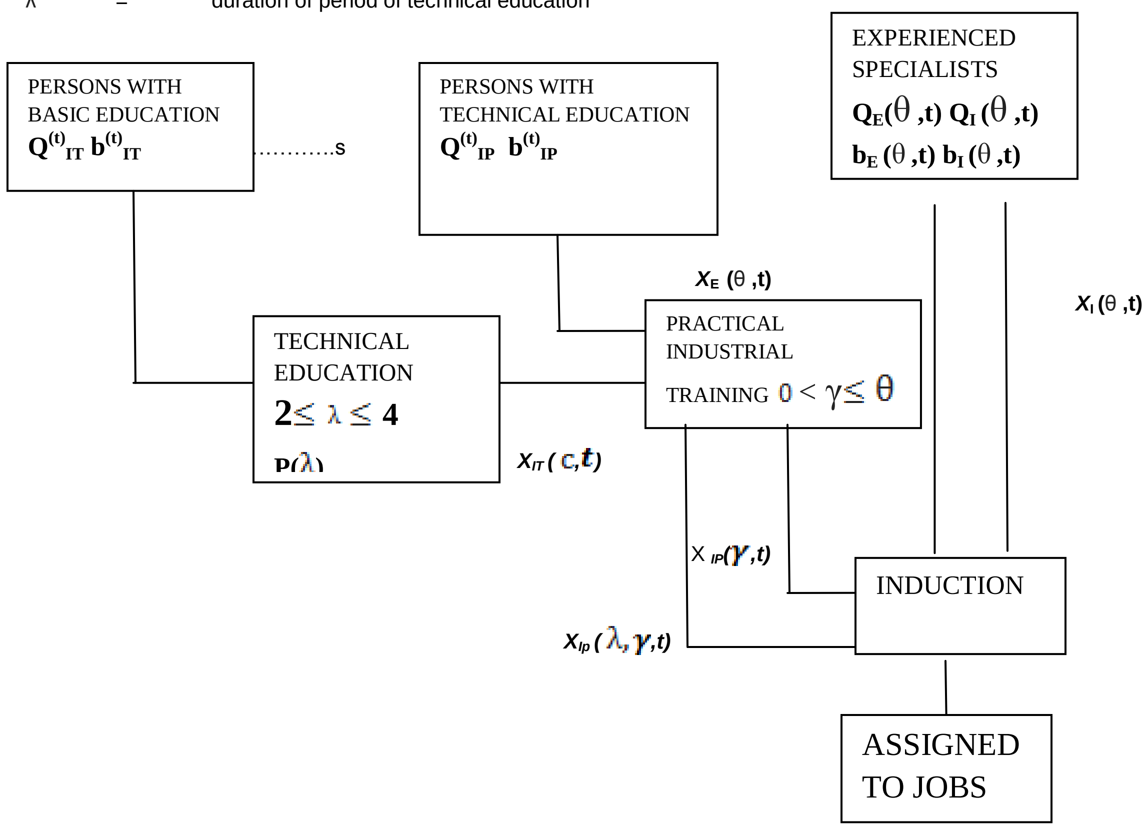


Figure 4-2 *STRUCTURAL MODEL FOR CRUDE OIL REFINING MANPOWER PLANNING*

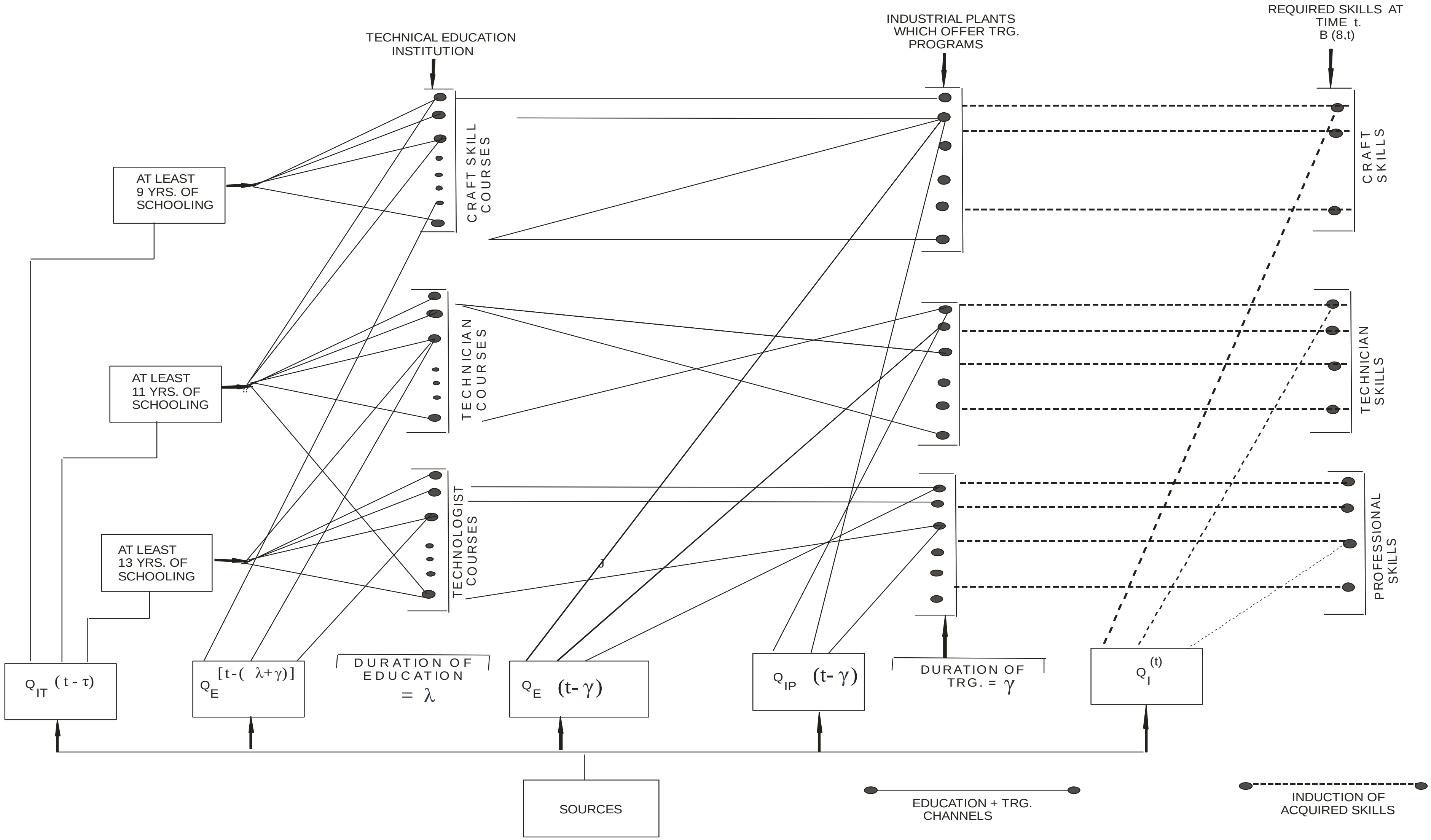


FIG. 4- 3 *DIAGRAMMATIC REPRESENTATION OF EDUCATION AND TRAINING PROCESS*