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Manpower planning with System dynamics and Business Objects

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Organisations tend to be hierarchical with a finite number of levels (ranks). Humans are considered as the most crucial, volatile and potentially unpredictable resource which an organisation utilises. If an organisation fails to place and direct human resources in the right areas of the business, at the right time, and at the right cost, serious inefficiencies are likely to occur creating considerable operational difficulties or even business failure. In order to achieve this the co-ordination of demand and supply is required, together with the monitoring and assessment of productivity and technological changes. Staff moves around the organisation in a variety of movements and flows. It is clear that it is difficult to track and monitor these movements without the complexity of qualitative factors and the projection of resource mismatches.

Traditional approaches such as Markov based models are highly concentrated on the mathematical aspects to represent the manpower planning process. In order to overcome the problems of traditional approaches a new technique is required which combines the rich problem structuring of "system thinking" with the flexible analytical power of quantitative methods. Since system thinking enables the conceptualisation of a situation in the form of a "rich picture" that contains the necessary interconnections between its various entities, the mathematical intricacies of each entity could be abstracted or usually eliminated. As a result realities could be presented in a comprehensible format. The technique that realises the operational and representational aspects of a business problem is system dynamics. Such models are far superior in process terms since they are not "black boxes" but totally understandable to those involved.

The proposed architecture unifies System Dynamics with Business Objects in a single framework that enables the dynamic communication of statistical information from the operational system of an organisation to the system dynamics model. This information could be: the total number of employees in each rank, transfers rates between ranks, wastages, promotions, employees productivity and so forth. All this information corresponds to the current state of the organisation and is fed into the simulation model dynamically. This leads to up to date supply of information to the simulation model and subsequently more accurate simulation results.

1. Introduction

Organisations tend to be hierarchical with a finite number of levels (ranks). Humans are considered as the most crucial, volatile and potentially unpredictable resource which an organisation utilises. If an organisation fails to place and direct human resources in the right areas of the business, at the right time, and at the right cost, serious inefficiencies are likely to occur creating considerable operational difficulties or even business failure. In order to achieve this the co-ordination of demand and supply is required, together with the monitoring and assessment of productivity and technological changes. Staff moves around the organisation in a variety of movements and flows. It is clear that it is difficult to track and monitor these movements without the complexity of qualitative factors and the projection of resource mismatches.

This paper proposes a technique that enables the dynamic communication of statistical information from the operational system of an organisation to the system dynamics model. This information could be: the total number of employees in each rank, transfers rates between ranks, wastages, promotions, employees productivity and so forth. All this information corresponds to the current state of the organisation and is fed into the simulation model dynamically. This leads to up to date supply of information to the simulation model and subsequently more accurate simulation results.

2. Background of Manpower planning

In the early 1970s many companies were planning significant expansion. During this period such companies were quick to realise that the key to success was an adequate supply of appropriately skilled people. This led to the emergence of human resource planning as a personnel management tool. Manpower planning is the process of ensuring that the correct number of human resources are available at the right time at the right place. Companies attempt to forecast their human resource requirements for the medium to long term. In order to do that they need appropriate analytical tools. Much effort was devoted to developing tools and techniques to assist managers with their planning. Many of these were based on the theory of stochastic processes and more specifically the concept of Markov chains [Bowel, 1974].

In large organisations the flow of individuals between the various ranks is a task which requires careful and detailed monitoring. Over a number of years patterns of behaviour may emerge and in many cases the role of manpower planning is to build a picture of such resource flows. In a stable environment where the features and characteristics of product and labour markets are expected to evolve in a predictable and orderly fashion, a model of long-term patterns of employment within the organisation would emerge. This would show the expected number of retirements, the expected turnover of staff, within departments and the average number of staff which leave for involuntary reasons. This can give a broad and rather basic picture of staff turnover. Hence it can also be used to provide valuable information on timings and rates for replenishing staff. To sum up, to maintain stable levels of employees over time management, required data on where, when and how many employees need to be recruited.

3. Manpower Models

Manpower models can belong to a variety of categories. Traditionally manpower models were thought as mathematical representations of the relationships of a manpower system. The representations are normally in the form of mathematical equations, which themselves express the manpower process. Manpower systems are normally considered as complex systems in which their counterparts interact with each other in order to accomplish the desired outcome [Khoong, 1996]. A typical manpower system is presented in figure 1. Rectangles represent “stocks” and arrows represent movements between the various entities of the system and they are known as “flows”. “Stocks” accumulates data of the same type and “flows” are pipelines of data that belong to the same type. In practice, manpower systems are considerably more complicated than the one shown in figure 1. A more realistic model is shown in figure 2 which represents an organisation’s management structure. Subsystems also can and need to be identified so it becomes necessary to distinguish between the system by age, length of service or by department and section. The result is what managers are faced with, an extremely complex dynamic system of interrelationships. Even if the flows are stable, which they never are, the people themselves are continuously changing and as a result changing the jobs as well. Due to the complexity of such systems managers need assistance to understand them first and then manage them. This is the purpose of a model. [Bramham, 1994], [Bramham, 1978].

Figure 1 Typical manpower system

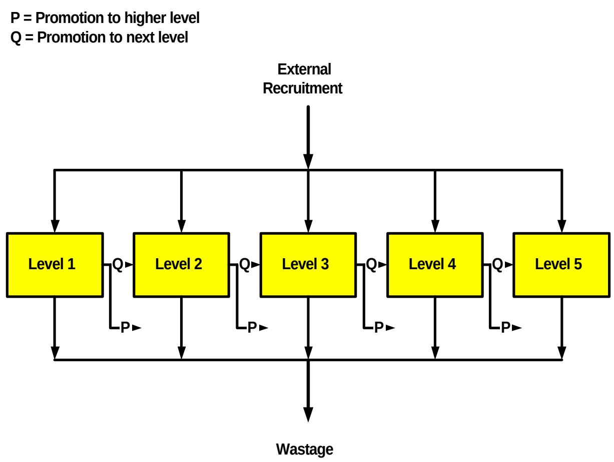

Figure 2 A more complex manpower system

4. Markov and Renewal Manpower models

Markov models start with a given group of employees that exist in a level of the organisation, given the flows in and out of each level, (i.e. recruitment and promotions from outside the system together with wastage) they estimate the population of the level in the future. This type of models is particularly useful when the knowledge of existing employees is available together with the probabilities of flows between succeeding years and the required future manpower is not known. Markov models are based on the assumption that future employees in any level of the organisation are determined not so much by the numbers required in that level but by the promotions and recruitment encouraging movement up through the system. Because of this characteristic of “pushing”, Markov models are often called “push” models. Young and Almond's model belongs to the category of Markov models [Grinold et al., 1997]. The basic assumption is that an employee in a particular rank has a fixed probability of promotion in a given year. Employees receiving promotions depend on the number of eligible staff in the rank below. There is no requirement for a vacancy to exist in the higher rank. The central equation used in this type of models is shown below [Bowey, 1974]].

$$\mathbf{n}(t+1)=\mathbf{n}(t)P + R(t+1)\mathbf{r}$$

Where n(T) is the vector of stocks at time t – the number of employees in each rank. P is the matrix of transition probabilities between each pair of ranks, r is a vector of probabilities of a recruit starting off in each particular rank, and R(t) is the number of new recruits at time t.

Renewal models concentrate on the basic assumption that requirements are met by changes in promotions and recruitment rates. Knowing the manpower requirements what is required is knowledge of how much recruitment and how many promotions should take place to satisfy them. In this way employees are "pulled" through the system to meet predetermined requirements. Because of this, renewal models are often called "pull" models. These models are useful when the future manpower requirements are known within reasonable limits and what flows are required to meet the must be identified.

Since "push" and "pull" models are not strong enough when they were used individually, a combined approach was introduced named "push-pull" that employed the characteristics of both models.

Despite their advantages, these models were often highly mathematical, demanding considerable mathematical sophistication for understanding. As the techniques developed, the mathematics behind them became even more complicated for individuals to comprehend other than trained mathematicians. Unfortunately for the successful implementation of these techniques, mathematicians tend not to become personnel managers and even fewer personnel managers are willing to study mathematics.

5. System Dynamics Approach to Manpower Planning

Existing human resource planners are interested on techniques that are usable by non-mathematicians. Traditional approaches though such as Markov based model are highly concentrated on the mathematical aspects to represent the manpower planning process. Ackoff, [Ackoff, 1979] characterised real business systems as "messes" because of their complexity and their amorphous nature.

In order to overcome the problems of traditional approaches a new technique is required which combines the rich problem structuring of "system thinking" with the flexible analytical power of quantitative methods [Parker et al., 1996]. Since system thinking enables the conceptualisation of a situation in the form of a "rich picture" that contains the necessary interconnections between its various entities, the mathematical intricacies of each entity could be abstracted or usually eliminated. As a result realities could be presented in a comprehensible format. The technique that realises the operational and representational aspects of a business problem is system dynamics. In general, system dynamics models are easier and more flexible to formulate and solve, they provide equal or even greater analytical power than Markov based models. Additionally, such models are far superior in process terms since they are not "black boxes" but totally understandable to those involved.

Comparing the two techniques in the area of manpower planning the following advantages of system thinking oven Markov based models were identified.

Reduced complexity compared with Markov models
Markov based models can be applied to almost every business requirement. The problem with Markov models is based on the fact that as more reality is incorporated into the model in order to capture the richness of the problem, the analysis becomes mathematically more complex. This does not apply to the same extent for the system dynamics approach.

Representation
System thinking approach provide the means for modelling complex situations in a way that ensures that all the assumptions are consistent, explicit and easily communicable. In addition providing analytical power to process rich models without complex mathematics. The use of flowcharting techniques brings the modeller and decision-maker closer to each other and as a result improves the conceptualisation of the system in hand.
[Parker et al., 1996]

6. The proposed methodology for Manpower planning

The purpose manpower planning methodology is based on embedding business objects and system dynamics models into a single framework. The business objects are used for the operational aspects of the system and simulation models embedded into the business objects for the simulation aspects of the system.

Business objects are objects that represent a person, place, thing or concept in the business domain. They package business procedures, policy and controls around business data. Business objects serve as a storage place for business policy and data, holding together in a coherent unit the right business policy with the right data and ensuring that data is only used in a manner semantically consistent with business intent [OMG, 1992].

Zeffane [Zeffane, 1994] proposed a matrix model for manpower planning that employs the principles of Markov chain in order to incorporate all the information that influence the manpower planning process. However unlike previous models based on the theory of Markov, Zaffane's model caters for a number of internal and external constraints by way of a series of incremental and simultaneous iterations. The model consists of a core matrix featuring personnel forecasts by levels of employment, and a series of peripheral matrices representing the factors that influence changes in the core matrix (figure 3). Each cell of the peripheral matrices features coefficients (probabilities) for each type of constraint and for each level of the organisation. The interface of the elements of the peripheral matrix with the elements within the core matrix produces a new set of forecasts for each rank. The interaction of the core matrix with the peripheral is based on the Markov chain principles. Information concerning the coefficients/rates of the matrices could be derived from historical data by using simple probabilistic, or stochastic estimates for a given time period-normally from a human resource information system. In addition to the internal constraints the model is also influenced by external to the organisation information. These are realised as a higher level peripheral matrices which are normally directly linked to a computerised system.

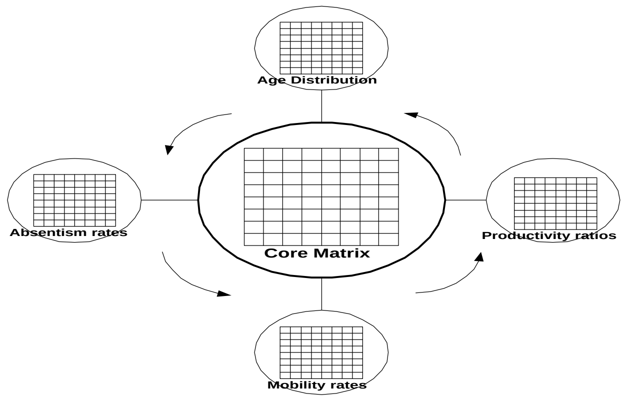

Figure 3 Zeffane's multimatrix model for manpower planning

Zeffane's approach attempts to incorporate as much information as possible in the manpower-planning model in order for it to produce more accurate results. The main drawback of the model is the high mathematical complexity and the lack of direct mapping to real business concepts. Moreover the isolation of Zeffane's model from the organisation's operational model generates integration compatibility problems.

The methodology proposed in this paper is similar in a way to Zeffane's model. The constant supply of the system dynamics co-models with internal as well as external organisational information constitutes the main commonality between the two approaches. However the proposed methodology eliminates the disadvantages of Zeffane's model by directly mapping the simulation co-models to real business entities. The integration of the operational and simulation models into a single framework eliminates the need for complicated integration mechanisms (in order to benefit from the historical information accumulated in the operational model, which could easily be transformed into stochastic information for the simulation model) which would in turn constitute an obstacle to the evolutionary characteristics of the approach. Moreover instead of concentrating on a centralised(monolithic) approach where each element supports its encapsulating entity, the proposed methodology is based on the object oriented paradigm and subsequently maintains its advantages.

In the proposed methodology business objects are composed of business rules, a recorder, a simulation co-model(system dynamics) and their operational functionality. Each of the components of business objects is described below in the context of the manpower planning case study.

Recorder
Manpower planning is based entirely on information concerning the current state of the organisation. Information is needed regarding internal as well as external influences of the organisation [Zeffane, 1994]. Internal information such as the current number of employees in each rank, the age distribution of each rank, the performance of each employee, absenteeism factors and so forth. External information such as labour market demand, unemployment, economic, marketing, financial and so forth. Information such as the age distribution in an organisation influences the absenteeism factor due to increased illness probability due to age [Ekamper, 1996]. Length of employment influence the wastage rate, since employees which are new to an organisation are more likely to leave rather those who have been employed for long time. Moreover external factors such as the decree of unemployment will influence the wastage factors. Information such as the economic and political would probably influence the recruitment rate. Organisation plans for expansion or the initialisation of a new marketing product, if not taken into consideration regarding the manpower levels, can act as an obstructing factor for the successful operation of the organisation.

The application of the recorder object enables all these and is illustrated in figure 4. Each rank (level) of the organisation corresponds to a business object in the operational model. Ranks interact with the employee business object in order to accumulate all the necessary information concerning the current workforce of the organisation. This information is subsequently passed to the recorder which records them into the database. In addition the recorder extracts from collaborating objects information concerning the wastage rates, current vacancies, and recruits. Business objects also incorporate the necessary functionality for the operational aspects of the rank that they represent. These could be the tasks that employees assigned to the particular rank are responsible to perform. Completing these tasks enables the recorder to record the performance of each employee.

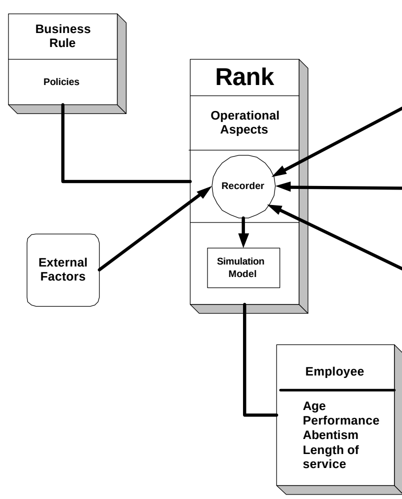

Figure 4 The Recorder encapsulated in each business object is responsible for the accumulation of information concerning the current workforce of the organisation as well as information concerning external influences to the organisation.

This can be achieved in cases where the tasks are performed on the computer. In these cases the system monitors the time spent by each employee on each task. For manual tasks, alternative techniques could be applied. Information concerning the performance is recorded for simulation purposes by the recorder. In addition to internal factors that influence manpower planning the recorder records information concerning external factors. Such information is provided by collaborating business objects which concentrate on issues external to the organisation (labour market, unemployment rates etc).

Business Rules

In order to enforce the organisation's policies on the operational and simulation processes, the "Business Rule" object is employed, so that the managers can specify the policies that they wish to apply to their manpower. Policies such as the maximum and minimum numbers of employees in each rank, the maximum and minimum numbers of years in a rank before promotion, and so forth are incorporated into the "business rule" object and are passed to the rank business object during operation and simulation. Policies are initially converted into their equivalent numerical format and subsequently passed to the simulation model.

Simulation Model

The simulation co-model incorporated in the business objects is based on system dynamics. Each co-model interacts with other co-model of collaborating business objects. Figure 5 depicts a generic model of a typical organisation. Each level (rank) of the organisation is divided into a number of years. These years denote the length of time that employees stay at a certain level. Employees flow from year to year until they reach the maximum number of years that they can remain at the same level before being promoted. Wastage is denoted by employees leaving the organisation voluntarily or compulsorily. The model represent a generic representation for manpower planning. The causal loop diagram for each rank of the organisation (therefore and for each Business object that represent that rank) is depicted in figure 6.

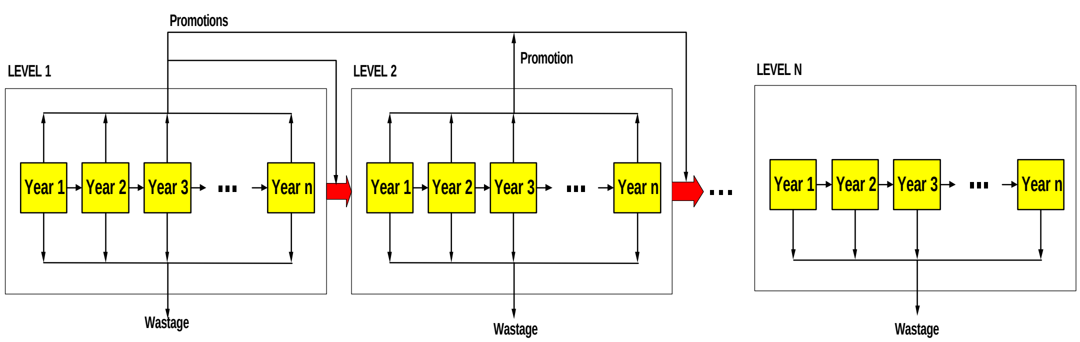

Figure 5 A high level representation of a manpower planning model

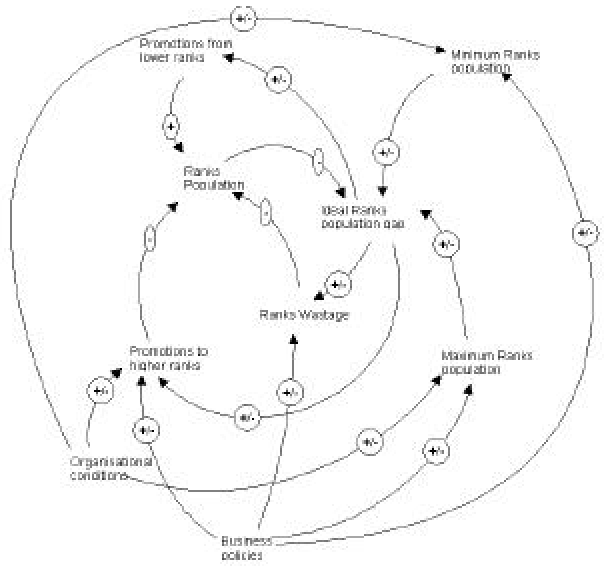

Figure 6 Causal loop diagram

7. Conclusions

The integration of business objects with system dynamics has proven to be beneficial in the area of manpower planning. The incorporation of business rules to guide each business object and its embedded system dynamics co-model enables the co-ordination of both operational and simulation models. Due to the employment of a recorder object in each business object, important information concerning the manpower model could be collected during operation and subsequently supplied to the simulation model for processing. The co-operation of the various business objects and the exchange of information concerning their embedded simulation models enable the utilisation of a variety of information types concerning the simulation. The application of the methodology in manpower planning revealed considerable benefits compared to monolithic simulation models, such as elimination of continuous re-informing sessions concerning the current state of organisation's manpower. Intelligent decisions can be made by the governing business objects during the simulation process which identifies the most appropriate sequence of actions to be followed by the practising managers. Since the operation and simulation of manpower is conducted in the same framework there is no redundancy of information and no information gathering and transfer costs.

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