CHEMICAL ENGINEERING TRANSACTIONS
VOL. 70, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Timothy G. Walmsley, Petar S. Varbanov, Rongxin Su, Jiří J. Klemeš

ISBN 978-88-95608-67-9; **ISSN** 2283-9216
DOI: 10.3303/CET1870047

P-graph Approach to Planning Human Resource Expansion for Universities in Transition

Kathleen B. Aviso[a,*], Feorillo P. A. Demeterio III[b], Rochelle Irene G. Lucas[c], Raymond R. Tan[a]

[a]Chemical Engineering Department, Gokongwei College of Engineering, De La Salle University, Manila, Philippines
[b]Filipino Department, College of Liberal Arts, De La Salle University, Manila, Philippines
[c]Department of English and Applied Linguistics, Brother Andrew Gonzalez College of Education, De La Salle University, Manila, Philippines
kathleen.aviso@dlsu.edu.ph

In the developing world, many universities are currently in the midst of transition from being purely teaching institutions focused on educational and degree-granting functions, towards becoming more research-intensive organizations that contribute new knowledge. Such transitions are usually hampered by difficulties associated with resource constraints, excessively bureaucratic support processes, and, most importantly, a staff profile inappropriate to the increased demands of research activities. Thus, systematic approaches for planning human resource expansion in such cases can facilitate such transitions. In this work, a P-graph approach is developed as a decision support model for planning staffing levels in universities that seek to expand research activities. Different staff categories are represented as process units in the P-graph model, while interactions among staff categories are modeled as process streams. This methodology is illustrated with a hypothetical but representative example of a typical Philippine university.

1. Introduction

Leading universities today were either founded as research universities, or as teaching institutions that were re-engineered into research universities prior to the age of mass higher education. These leading research universities eventually serve as the powerhouses of knowledge creation and innovation that consequently fuelled the socio-economic development of their respective home countries. In developing countries, specifically those that experienced long years of colonial domination, having a research university usually involved recent re-engineering some existing teaching universities. As these earmarked teaching universities have a great number of staff of students, their transition into research universities needs not only considerable financial resources and political will, but more so strategic human resources planning, which needs to be holistic and integrated in order to avoid skewed configurations of teachers, researchers, administrators, students and support staff. In the Philippines, for example, the few universities that are trying to expand their research capacities have focused too much on hiring research professors without considering whether they have enough students and support staff. Higher educational institutions (HEIs) that are in transition from being teaching universities to research universities, or simply interested in increasing their research production, therefore need a strategic tool for analysing their current human resource configurations, for determining their optimal human resources configuration relative to their desired level of research productivity, and for monitoring every stage of their on-going reconfiguration.

The main functions of human resource planning in an institution are to aid in executing its plans and policies. Both direct human resources and staff for support services should be considered (Yousif and Shaout, 2016). In an HEI undergoing transition to a research university, an extensive review of the functions of its manpower is imperative to address the growing targets. Rigorous analysis of the nature of the work assigned to the institution’s personnel is essential. Furthermore, human resource management should also consider the different processes and management strategies to contribute to the growth of the organization (Kucharcíková et al., 2015). A summary of the personnel in the university alongside their functions are shown in Table 1.

Table 1: Summary of Human Resource Classification and their Functions

Human Resource Classification	Functions
Faculty	General academic staff with teaching, research and extension functions; the relative proportion of these functions can give rise to further subcategories.
Teaching assistant (TA)	Contractual staff engaged to assist in teaching-related functions.
Research assistant (RA)	Contractual staff engaged to assist in research-related functions.
General support staff	Staff employed for various organizational support functions (e.g., finance, procurement, legal, etc.)
Faculty with administrative functions	Administrators appointed to part-time management functions, while still retaining partial faculty duties.
Pure administrators	Administrators appointed to full-time management functions.

Strategic human resource management is imperative in the attainment of an institution's competitive edge (Allui and Sahni, 2016). There is relatively sparse literature on the use of systematic decision support tools to aid in human resource planning in HEIs. Early examples of methods used include goal programming (Feuer, 1985) and simplified population balance models (Wei, 1998).

Input-output (IO) models were first developed for the analysis of economic systems by Leontief (1936). The methodology is described extensively by Miller and Blair (2009). The application of the IO modelling framework to the analysis of large-scale social systems was proposed by Correa (2002). On a smaller scale, this approach has also been proposed as a useful approach to planning human resources within organizations (Correa and Craft, 1999). This planning methodology has been applied to projecting staffing requirements in various contexts such as libraries (Correa and Correa, 1996), municipal offices (Correa and Guajardo, 2001) and hospitals (Correa and Parker, 2005). A direct matrix inversion procedure is used to solve for staffing levels for organizational systems with zero degrees of freedom. A recent extension used a fuzzy optimization formulation to determine optimal personnel reallocation during a temporary crisis in an understaffed organization (Aviso et al., 2018). Meanwhile, the possibility of modelling IO systems within the P-graph framework was established by Aviso et al. for economic networks (2015). This development suggests the broader applicability of P-graph to input-output systems in general, and to human resource planning in particular (Aviso et al., 2017).

In this work, a P-graph model is developed as a decision support tool for human resource planning in HEIs in developing countries, where rapid transitions towards increased levels of research can strain existing levels of human resources. These difficulties apply to both core personnel (i.e., academic staff) as well as to administrative support (e.g., finance, legal, etc.) and management (e.g., department heads, deans, etc.). Planning staffing can thus benefit from scientific decision support via P-graph. The rest of this paper is organized as follows. Section 2 gives a description of the P-graph framework. Section 3 illustrates the proposed model on a representative case study based on typical HEIs in the Philippines. Finally, conclusions and prospects for future work are given in Section 4.

2. P-graph Framework

P-graph is a rigorous graph-theoretic framework for solving Process Network Synthesis (PNS) problems. The five fundamental axioms for PNS problems were given by Friedler et al. (1992a) based on information common to PNS problems in chemical engineering design problems. These axioms form the basis for the development of efficient algorithms for elucidating combinatorially feasible networks (Friedler et al., 1992b). The framework also provides a rigorous means of identifying a maximal structure given a set of system component units and streams (Friedler et al., 1993).

The P-graph framework consists of three component algorithms. Maximal structure generation (MSG) is the rigorous, automated generation of a structure which represents the union of all possible network structures for a PNS problem. Solution structure generation (SSG) is the rigorous elucidation of all combinatorially feasible network structures (i.e., subsets of the maximal structure) for a PNS problem. Accelerated branch and bound (ABB) is the efficient determination an optimal network, which specified the best structure and flow rates based on a predefined optimization criterion. ABB executes an efficient search of the solution space as compared to conventional the branch-and-bound algorithm by utilizing information from MSG and SSG to eliminate redundant solutions, thus resulting in drastic improvements in computational efficiency.

P-graph has the capability to generate the n-best solutions to any given PNS problem. This feature is especially useful for practical decision-making problems. Such near-optimal solutions may have performance levels virtually equivalent to, or indistinguishable from, that of the true optimum. While P-graph was originally developed to solve PNS problems encountered in the design of chemical plants, this approach has been extended to a wide range of structurally analogous problems; many of these early applications are discussed in a review paper by Lam (2013). More recent developments as well as broader geographic spread of research interest in P-graph are discussed by Klemeš and Varbanov (2015), while a review of its success and assessment of future directions are outlined in Varbanov et al. (2017). The relationship between P-graph and economic input-output systems was established by Aviso et al. (2015), and subsequently applied to input-output models of organizational systems (Aviso et al., 2017). In addition, Tick (2007) pioneered the use of P-graph for business process workflow optimization.

Human resource planning can be modelled in P-graph by identifying categories of staff and representing these as process units, while the functions provided by each type of staff are represented as material or product streams. A teaching faculty (process unit labelled FAC_T) for example is expected to teach and provide consultation (material or product stream labelled TEACH). However, the teaching faculty will require support services (node labelled SUPPORT) and receives general supervision (node labelled SUPERVISION) from top management. The P-graph form is shown in Figure 1.

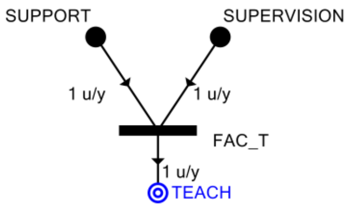

Figure 1: P-graph representation of teaching faculty in HEI

3. Formal Problem Definition

In the proposed methodology, the problem addressed via the P-graph model can be formally stated as:

- Given a set of homogeneous categories of employees or workers, within which work assignments are assumed to be fully interchangeable, and for which average cost of compensation is known;
- Given a set of types of work flows or tasks, which are associated to the worker categories as inputs or outputs;
- Given that each worker category has a fixed set of workflow inputs and outputs, which reflect the worker's job description (i.e., deliverables) and interactions with co-workers;
- Given that the institution has a predefined set of net output for each of the workflows;
- The objective is to determine the staffing level in each worker category to deliver the required net output at minimum cost.

4. Case Study

A hypothetical HEI is used in this example, with seven human resource categories as indicated in Table 1. Faculty are categorized into pure teaching, pure research and mixed functions. In addition, six types of interaction between the different staff categories are identified based on the staff job functions. These include general supervision/management, research mentoring, research, teaching (including consultation), knowledge transfer and support. All workflows are measured in man-hours per week, but these are assumed to be proportional to the actual output demands (e.g., number of students, number of journal articles published, etc.). The interaction between staff categories is represented by arcs. The P-graph representation of the HEI can be generated using MSG as shown in Figure 2. The interactions are summarized in Table 2 together with the average salary for each category.

Using SSG, it is possible to identify 86 different structures indicating that different combinations of staff categories can exist in the HEI. Due to space constraints, these potential alternative structures are not shown here. The baseline scenario assumes the weekly total output for teaching is equivalent to 18,000 man-hours, while those for research and knowledge transfer both require a minimum of 1,000 man-hours. This corresponds to an output profile of 90 % teaching, 5 % research and 5 % knowledge transfer. The academic staff requirement is 961 faculty members, of which 546 have only teaching duties, 169 have combined teaching and research, 246 faculty administrators. Also, 565 support staff are needed. The initial total weekly cost of personnel salaries is € 575,734. The HEI then seeks to increase research and knowledge transfer output by 300 %, while maintaining teaching output levels. The new requirements are 18,000 man-hours for teaching, 4,000 man-hours of research and 4,000 man-hours of knowledge transfer. In addition, the number of teaching assistants and full-time researchers is limited to 200 and 300. The cost-optimal network is shown in Figure 4. This solution requires 278 teaching faculty, 78 teaching assistants, 53 faculty that do both teaching and research, 300 research faculty, 667 research staff plus 353 faculty administrators. This new structure requires a total of 984 faculty, which is a 2.4 % increase compared to the baseline. There is now a need to employ research staff, teaching assistants and faculty dedicated to research. The need for teaching assistants is the indirect result of having 49 % of previous teaching faculty take on more research activities. The support staff requirement has also increased by 12.6 % to 636.Total cost of personnel salaries increases by 37.6 % to € 792,084.

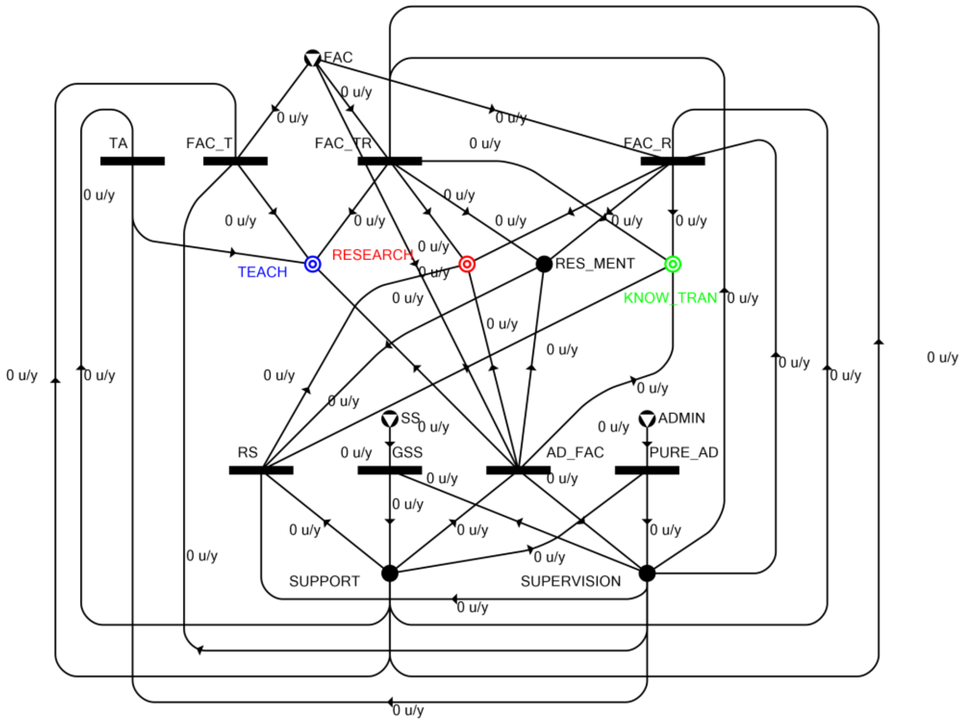

Figure 2: Maximal structure of an HEI

Table 2: Workforce interaction in HEIs in man-hours/week

	Faculty (Teaching)	Faculty (Research)	Faculty (Teach/ Research)	Teaching Assistant	Research Staff	Support Staff	Admin/ Faculty	Pure Admin.
General supervision	–2	–2	–2	–2	–2	–4	15	40
Research mentoring	0	6	3	0	–4	0	2	0
Research	0	24	12	0	36	0	8	0
Teaching	36	0	18	36	0	0	12	0
Knowledge Transfer	0	6	3	0	2	0	2	0
Support	–12	–12	–12	–8	–10	40	–30	–60
Salary (€/week)	450	600	550	200	200	180	550	750

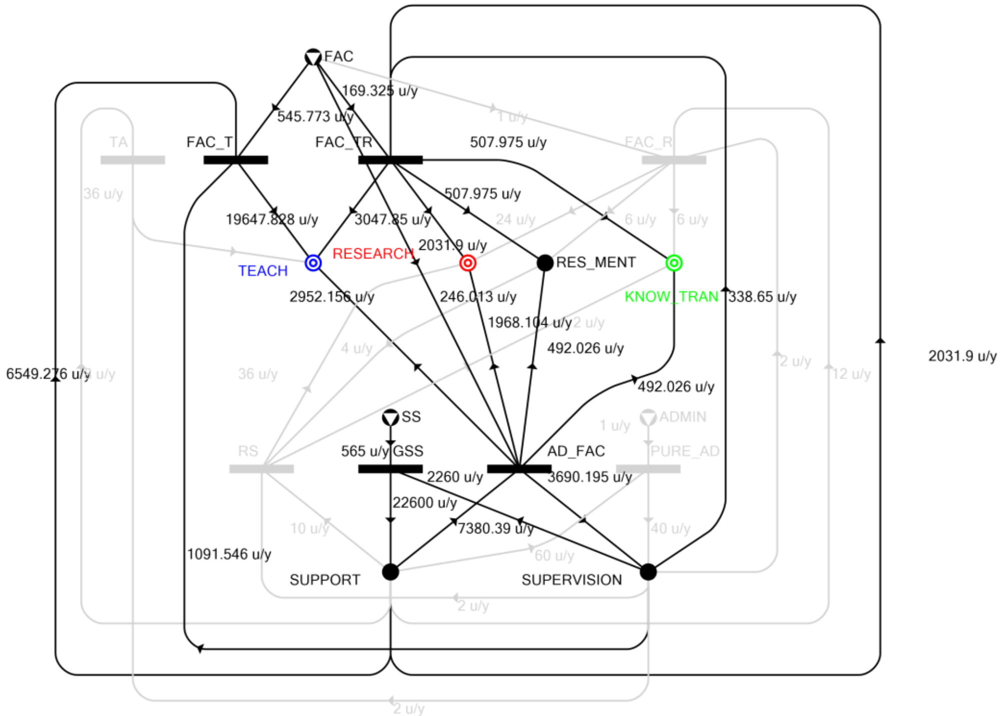

Figure 3: Baseline staffing level of HEI

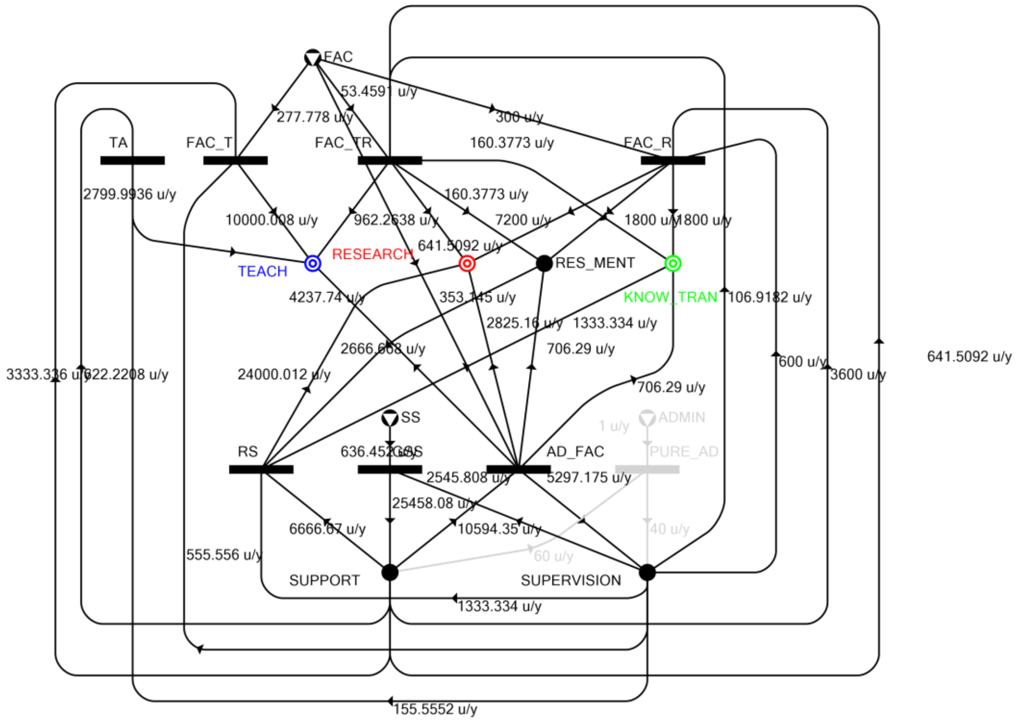

Figure 4: Optimal staffing level for 300% increase in research and knowledge transfer output

5. Conclusions

This work presents a P-graph methodology for human resource planning in HEIs. This approach allows optimal and near-optimal staffing levels in different human resource categories to be determined to meet strategic requirements for expansion of research capacity and output in an HEI. Workflow representation in the P-graph model allows indirect effects of expansion to be accounted for, as illustrated using a hypothetical case study. Indirect effects are difficult to deduce intuitively, but in practice, failure to account for them can result in process bottlenecks within the HEI. Future work can include multi-period P-graph models, as well as integration within a decision analysis framework to compare alternative near-optimal networks.

References

Allui A., Sahni J., 2016, Strategic human resource management in higher education institutions: Empirical evidence from Saudi, Procedia – Social and Behavioral Sciences, 235, 361–371.

Aviso K.B., Cayamanda C.D., Solis F.D.B., Danga A.M.R., Promentilla M.A.B., Santos J.R., Tan R.R., 2015, P-graph approach for GDP-optimal allocation of resources, commodities and capital in economic systems under climate change-induced crisis conditions, Journal of Cleaner Production, 92, 308–317.

Aviso K.B., Mayol A.P., Promentilla M.A.B., Santos J.R. Tan R.R., Ubando A.T, Yu K.D.S., 2018, Allocating human resources in organizations operating under crisis conditions: A fuzzy input-output optimization modeling framework, Resources, Conservation and Recycling, 128, 250–258.

Aviso K.B., Cayamanda C.D., Mayol A.P., Tan R.R., 2017, P-graph approach to human resource reallocation in industrial plants under crisis conditions, 6th International Symposium on Advanced Control of Industrial Processes, May 28-31, Taipei, Taiwan, Article number 7983768, 131–136.

Correa H., 2002, An input-output operationalization of societal systems, Journal of Socio-Economics, 31, 115–123.

Correa H., Correa V. 1996, An application of input-output analysis to the administration of a library, Library and Information Science Research, 18, 343–356.

Correa H., Craft J., 1999, Input-output analysis for organizational human resources management, Omega, 27, 87–99.

Correa H., Guajardo S.A., 2001, An application of input-output analysis to city's municipal government, Socio-Economic Planning Sciences, 35, 83–108.

Correa H., Parker B.R., 2005, An application of organizational input-output analysis to hospital management, Socio-Economic Planning Sciences, 39, 307–333.

Feuer M.J., 1985, Organizational decline, extended work life and implications for faculty planning, Socio-Economic Planning Sciences, 3, 213–221.

Friedler F., Tarjan K., Huang Y.W., Fan L.T., 1992a, Graph-theoretic approach to process synthesis: Axioms and theorems, Chemical Engineering Science, 47, 1973–1988.

Friedler F., Tarjan K., Huang Y.W., Fan L.T., 1992b, Combinatorial algorithms for process synthesis, Computers and Chemical Engineering, 16, 313–320.

Friedler F., Tarjan K., Huang Y.W., Fan L.T., 1993, Graph-theoretic approach to process synthesis: Polynomial algorithm for maximal structure generation, Computers and Chemical Engineering, 17, 929–942.

Klemeš J.J., Varbanov P.S., 2015, Spreading the message: P-Graph enhancements: Implementations and applications, Chemical Engineering Transactions, 45, 1333–1338.

Kucharcíková A., Tokarcíková E., Blašková M., 2015, Human capital management – aspect of the human capital efficiency in university education. Procedia – Social and Behavioral Sciences, 177, 48–60.

Lam H.L., 2013, Extended P-graph applications in supply chain and process network synthesis, Current Opinion in Chemical Engineering, 2, 475–486.

Leontief W., 1936, Quantitative input and output relations in the economic system of the United States. Review of Economics and Statistics, 18, 105–125.

Miller R.E., Blair P.D., 2009, Input-output Analysis: Foundations and Extensions, 2nd ed., Cambridge University Press, Cambridge, UK.

Tick J., 2007. P-Graph-based workflow modelling, Acta Polytechnica Hungarica, 4, 75–88.

Varbanov P.S., Friedler F., Klemeš J.J., 2017, Process network design and optimisation using P-graph: The success, the challenges and potential roadmap, Chemical Engineering Transactions, 61, 1549–1554.

Wei J., 1998, A steady-state planning model for faculty balance, Industrial and Engineering Chemistry Research, 37, 2078–2080.

Yousif M.A., Shaout A., 2018, Fuzzy logic computational model for performance evaluation of Sudanese Universities and academic staff, Journal of King Saud University-Computer and Information Sciences, 30, 80–119.