



AALBORG UNIVERSITY
DENMARK

Aalborg Universitet

A numerical unhappiness function for allocating cadet engineers to placement positions

Lindsay, Euan; Mahinroosta, Reza

Published in:
29th Australasian Association of Engineering Education Conference 2018

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Lindsay, E., & Mahinroosta, R. (2018). A numerical unhappiness function for allocating cadet engineers to placement positions. In *29th Australasian Association of Engineering Education Conference 2018* (pp. 1-7).

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

A numerical unhappiness function for allocating cadet engineers to placement positions

Euan Lindsay and Reza Mahinroosta.

CSU Engineering, Faculty of Business, Justice and Behavioural Sciences, Charles Sturt University

Corresponding Author Email: rmahinroosta@csu.edu.au

STRUCTURED ABSTRACT

CONTEXT

All Australian engineering degree programs require students to have exposure to professional practice prior to graduation. At CSU Engineering, this takes the form of a compulsory sequence of four year-long paid cadet placements. The process of ensuring that all cadets are successfully matched with a host organisation (host) has significant complexity due to the diversity of types and locations of hosts, the discipline mix of placements and cadets' preferences and constraints. The management of ongoing partnerships with the hosts must be balanced with the ability of cadets to proactively and independently seek their own placements. An equitable and fair method of matching cadets to the hosts is required for ethical operation of the placement program.

PURPOSE

This paper presents the numerical "unhappiness function" that is used to determine the allocation of cadets to placement positions through a competitive marketplace process.

APPROACH

The competitive marketplace approach attempts to mirror an authentic recruitment process, but the constraints of having to finalise allocations in a timely manner means that compromises are required. The introduction of these additional constraints introduces unhappiness into the system, mostly through either hosts or cadets who do not get their first preferences as a result of the matching. The numerical unhappiness function quantifies five key sources of unhappiness, and weights each of them relative to each other, so that potential allocations of cadets to hosts can be compared impartially, and the optimum matching can be chosen.

RESULTS

Applying the numerical unhappiness function and exhaustively considering alternatives allows the optimum matching of cadets to hosts to be achieved. While all hosts for the first and second cohort of students seem happy up front with the concept of the "numerical unhappiness function" used to ensure the overall optimisation of allocation matching, they become unhappy when the optimised solution does not match their particular preferences. The key benefits of the approach, such as a simultaneous and timely conclusion to the allocation process, securing workplace opportunity for all potential cadets, and the removal of emotion from what is a potentially very high-stakes process, seem largely invisible to many of the participants.

CONCLUSIONS

Overall an objective utilitarian method of fairly allocating cadets to placements has been implemented, allowing us to manage the diversity of discipline and location preferences of the cadets without compromising our ability to meet the needs of the hosts. The certainty of general fairness has been a powerful tool in managing ongoing relationships with our partners, even with those who feel specifically disadvantaged by accepting their second or third preferences in a particular allocation round.

KEYWORDS

Industry placement, cadetship, industry engagement, work integrated learning

Introduction

CSU Engineering curriculum consists of three semesters' face-to-face, on-campus study (Project Based Learning (PBL) environment) followed by a series of four one-year paid cadet placements in the industry (Work Integrated Learning (WIL) environment). At the university, students work on virtual to real projects in a team environment mentored by their academics, interacting with other teams and communicating with regional communities and real clients. The curriculum aims at preparing work ready graduates and filling the skill gaps in the engineering graduates (Graduate Careers Australia, 2015). There is neither lecture nor exam in the curriculum, instead, students learn technical knowledge through online environments with the choice of applying for tutorial sessions. During the workplace, students work on real-world projects, reflecting on their learning, building their e-portfolio and doing their project thesis over the next four years. The curriculum outline has been described thoroughly by Morgan and Lindsay (2015).

All Australian engineering degree programs require students to have exposure to professional practice prior to graduation. This is highlighted in the Australian Council of Engineering Deans (Male & King, 2013). At CSU Engineering, this is enhanced by effective engagement between university and the industries and finding potential workplaces for students with the opportunities to experience an engineering workplace under effective supervision. For instance, the workplace environment, workplace discipline and potential supervisors are discussed in the suggested meetings. Once the relationship is formalised, a Memorandum of Understanding (MoU) will be signed by CSU Engineering and the hosts indicating their mutual cooperation to offer placement positions. Organisations that engage with the engineering program include public and private sectors, large, medium and small organisations with unique and multi-disciplinary activities.

Every CSU Engineering student does four one-year cadet placements; it is essential that we have a fair and transparent process of allocating cadets to their hosts. These placement positions are advertised on the university website for potential cadets, who have completed the three semester face-to-face component of the degree. The diverse range of workplace options and cadets' location preferences increase the complexity of the allocation process. In addition, there is a need for an appropriate timeline to complete the whole process, so that placements can start on time and with enough notice to both cadets and hosts to deal with administrative process such as employment contracts.

This allocation process is the focus of this paper. The process that ensures cadets are successfully and fairly matched with a host organisation and encourages university-industry partnerships, which must be balanced with the ability of cadets to proactively and independently seek their own placements.

Workplace pathways

CSU Engineering offers two pathways for cadet placement: a self-placement pathway, and a competitive marketplace. The self-placement pathway allows for cadets to find themselves their own placement via their own networks, or to remain with a host for a second or subsequent placements. These placements must meet the quality assurance process of the program; but provided the cadet has indeed found themselves a suitable host, they are able to directly place themselves.

The competitive marketplace process allows CSU Engineering to match hosts who are partners of the university to the pool of cadets who have not sought to self-place. This pool includes hosts who wish to draw multiple cadets into their organisations, hosts who wish to replace a previous cadet who has moved on, or hosts that have come to CSU Engineering to address a workforce need within their organisation.

The competitive marketplace process is intended to emulate a regular employment marketplace, although it does so with some very different overtones. The first key difference is that it is an allocation process, not a recruitment process, which means that ultimately each cadet is given exactly one allocation, rather than a variable number of job offers. The second key difference flows from this in that it ultimately resolves itself on a single day when the allocations are released – there are no iterations of applicants turning down offers and hosts having to then move on to second choice applicants who may or may not still be available. The allocation process works in three distinct phases: Preparation, Application and Allocation.

In the Preparation phase, the hosts undertake the necessary processes to become hosts. This includes the quality assurance processes regarding type of work and appropriate supervisors, and the signing of a Memorandum of Understanding with the University. The hosts also prepare a Position Advertisement for their placement offering, using a standard template that allows the cadets to compare the placements easily, and provides links to the appropriate information such as selection criteria for the position. This phase takes place over the summer, so that it is completed when the students return to study at the commencement of the autumn semester in February.

In the Application phase, which lasts throughout March, the cadets submit their applications for the advertised cadetships using the InPlace software platform. They are free to choose how many or how few they wish to apply for, with the physical location of the placements emerging as a key driver of behaviour in this regard. Cadets are also able to identify a single placement as their number one preferred choice.

In early April the academic team conducts a shortlisting process, providing each Host with a short list of applicants to interview throughout April. Each of the hosts conducts interviews according to their own criteria, and provides CSU Engineering with a ranking order of their preferred cadets. In addition they provide confidential feedback about their applicants, as well as feedback that can be released to the cadets. Hosts are required to return their rankings to the University by the end of April.

In the Allocation phase, the academic team takes the rankings of the hosts and the preferences of the students and determines the optimal allocation matching. Once the cadets have been allocated to hosts, the matchings are combined with the self-placement outcomes, and participants are notified on the second Tuesday in May. This provides adequate lead time for cadets to complete the necessary employment paperwork, and if necessary relocate prior to their placement commencing in July.

The ideal allocation of cadets to hosts would ensure that everyone received their first preference, and that no hosts or cadets were left without a match. The reality of the process is that this is not possible, and as such some unhappiness is inevitable. Some cadets are everyone's first choice; some remote hosts receive only limited numbers of applications of cadets whose first choice is elsewhere.

In order to make the allocation process as fair and efficient as possible, we have developed a Numerical Unhappiness Function to quantify this unhappiness, and thus allow us to evaluate and compare potential allocations to determine which matching minimises the overall unhappiness. This allows us to apply well-known and robust optimisation approaches to select the optimum matching. This paper details our Numerical Unhappiness function and illustrates how it works in practice using the excerpts from the first two live applications and anecdotal observations from the host and cadets involved.

The Numerical Unhappiness Function

A deliberate choice was made to focus upon minimising unhappiness rather than maximising happiness. This was driven by multiple factors for the overall best outcome for CSU Engineering, and for the hosts. The context of the process as an allocation process, not a recruitment process, was a crucial lens in determining this outcome. In a recruitment process an employer is proactively looking for the best case outcome in selecting a new staff member. In this allocation process, the hosts are commencing a partnership with the university, and while they are keen to secure the best candidate, it is the worst case fear of receiving a "dud" that is more powerful than the best case hope of the perfect applicant. It was also felt that unhappiness over a perceived poor outcome would persist longer than happiness over a perceived good outcome, and would also be more damaging to the establishment of the relationship.

The luxury of working with engineering organisations allowed us to take a numerical approach to quantifying unhappiness, and thus to provide a clear, objective and utilitarian mechanism as to how we would make the allocations of cadets to hosts. Four key sources of unhappiness were identified for inclusion into the function used to quantify unhappiness:

- A host organisation not receiving their first preference
- A cadet not being allocated to their #1 preference
- A host not receiving a cadet at all
- A cadet not being allocated to a placement at all

The hypothetical ideal allocation is one where none of these occur – all cadets are placed at their preferred host that ranked them as their number one preference. To determine how to compare actual

allocations it was necessary to determine a base unit of unhappiness, and then to quantify and nuance each of these sources into the function.

The base unit of unhappiness was chosen as the separation between consecutive rankings at interview by the host: for instance, the margin between a 2nd preference and 3rd. While this margin may in fact not be linear, it is nonetheless a clearly identifiable, and convenient to manipulate, quantum for use in the allocation process.

Having chosen this base unit, it was then necessary to determine the relative weightings of each of the different sources of unhappiness, which would then serve as the coefficients in the unhappiness function.

The first ratio was the First Choice Ratio, RF. This factor addresses the psychology of loss aversion by weighting the distance between a 1st and 2nd choice more highly than a single unit of unhappiness – essentially acknowledging that “not getting your first choice” is the key source of unhappiness, and that the marginal additional unhappiness of receiving number 3 instead of number 2 will be lesser. The default setting for this ratio was chosen as 1.5.

The second ratio was the Industry Importance Ratio, RI. This factor addressed the relative weighting of the hosts’ preferences to those of the cadets. Given the dependency of the program upon the hosts providing paid cadetships, the default setting for this ratio was chosen as 1.5.

The third ratio was the (unfortunately but aptly named) Orphan Ratio, RO. This factor addressed the cost of either a cadet or a host being left without an allocation in the process. No specific distinction was made in this factor between hosts and cadets, noting that the Industry Importance ratio would apply to hosts without an allocation. Given the impact upon the affected parties of not being matched, the default setting for this ratio was chosen as 5.0.

The fourth ratio was the No Orphan Ratio, RN. It became clear that there was an expectation that everyone would be given a match, and that there was an appetite to degrade the quality of other matches if this would allow us to avoid anyone missing out. As such an additional weighting was placed upon the first orphan for either cadets or hosts. The default setting for this ratio was chosen as 2.0

The fifth ratio was the Subsequent Orphan Ratio, RS. It is clear that there is a significant impact either to a cadet or a host of not receiving a match through this process; it was felt that for this to occur more than once to the same host organisation would be unfair, and that it would be appropriate to degrade some other matchings in order to select a different host organisation to miss out. The default setting for this ratio was chosen as 2.0

The application and allocation phases provide the two main inputs for the unhappiness function: cadets’ prioritised workplace options and cadet preferences from hosts. Combining these inputs and the ratios leads to the overall Numerical Unhappiness Function:

$$Total\ Unhappiness = RI \times \sum host\ unhappiness + \sum cadet\ unhappiness$$

It is significant to note that the function treats all cadets and hosts equally (with the exception of those who have previously not been matched). This has the advantage of eliminating any bias (deliberate or accidental) towards cadets and hosts on the part of the staff performing the matching process. The corollary of this is that it also does not account for any perceived sense of “deservingness” on the part of the cadets or hosts.

How the function was applied

The function is currently implemented using a spreadsheet, with each cadet having their own row and each host having their own column. The cells are populated with the ranked outcomes of the interview process, and with the cadets’ first preferences highlighted with a “+”. An extract of such a grid, anonymised from real data, is shown in Table 1.

The first allocations are “1+” allocations, where the cadet has been ranked the number one choice by their host, and the host is their first preference. These cadets and hosts are then removed from the

pool (implemented by hiding rows and columns), which reduces the degrees of freedom of the remaining allocations.

Table 1: Extract from initial allocation grid

	Host 1	Host 2	Host 3	Host 4	Host 5	Host 6	etc
Cadet 1		1	=1+				
Cadet 2			=1				
Cadet 3							
Cadet 4		2		1+		3	
Cadet 5						2	
Cadet 6					1		
Etc							

The next step is to focus upon hosts who have the smallest number of applicants. Because of the high penalty cost of not allocating a cadet to a placement, it is the hosts with only one or two applicants most likely to contribute to the overall unhappiness score. Hosts with only one live option are allocated that cadet, and that cadet is removed from the pool.

Cadets with only one live option are then considered; if they were highly ranked by this host they are allocated; otherwise the process continues.

The early steps in this process lead to an emergent baseline allocation – there are matches between hosts and cadets that are inevitable regardless of how the unhappiness function is weighted. Hosts with a single applicant that they are happy with are inevitably going to be allocated that cadet; cadets who are the number one choice of their preferred host are also inevitably going to be allocated. It is the later steps where the flexibility is required.

Ultimately a number of smaller sub-pools will emerge, with three or four cadets to match to three or four hosts. In this instance, alternative matching arrangements are considered through a branching decision tree. One cadet-host pair is tentatively matched; they are then removed from the sub-pool, and the process iterated. This is done for multiple branching options, and the lowest-scoring option is chosen as the eventual allocation.

The algorithm has within it a certain level of structural unhappiness; once a cadet has been ranked as the first choice of multiple hosts, it is inevitable that there will be some unhappiness generated. Similarly, when trying to match 12 cadets to 11 hosts, it is inevitable that someone will be left without a match. As such the optimisation process is geared to finding the lowest marginal unhappiness.

There is a significant amount of robustness checking performed on the final allocation. The overall allocation is reviewed to count the number of 1st, 2nd and so on preferences. For each non-1+ matching there is an inspection to see what changes would be required to improve that match, to confirm that improving that match would require equivalent or further degradation of other matches throughout the overall allocation.

There is also a robustness checking of the overall coefficients, where the best and second best allocations are compared. For each of the weighting factors, the value of that factor that would lead to a change in the optimal solution is determined, and then considered as to how unreasonable a weighting that would be.

Results

The placement process has been applied twice to match cadets to hosts; a pool of 14 cadets and 16 hosts in 2017, and a pool of 16 cadets and 13 hosts in 2018. In both instances the majority of hosts received their #1 preference, with around half (2017) and a quarter (2018) of cadets receiving their first choice.

In both instances a baseline allocation emerged quickly, with around half of all matches being stable across any allocation, either due to being a 1+ match, or the only live option for a host or a cadet.

Both instances exhibited significant structural unhappiness, with an imbalance between host and cadet numbers, and around a quarter of all cadets rated as the #1 choice by more than one host.

Ultimately the iteration of the algorithm has served to finalise matchings without the need for subjective decisions on the part of staff within CSU Engineering. The weightings within the Unhappiness Function have been sufficient to allow for marginal differentiation between allocations.

For the most part, the cadets seemed happy with their allocated placements. While those who received their first preference were happier, overall most cadets were happy to have been allocated a host.

Cadets who were not matched to hosts have been understandably disappointed, but for the most part have then been proactive in seeking assisted self-placements subsequent to the matching process. This subsequent matching process has run much smoother because we are able to reassure potential hosts that their cadet has been unmatched in order to minimise overall unhappiness, rather than because the cadet is undeserving of a placement themselves.

The response of the hosts was mostly positive, which is due in large part to the majority of them receiving their first preference cadet. For those organisations not receiving their first choice, responses were mixed.

Hosts' responses to receiving a 2nd or lower preference cadet appeared to match their acceptance of the placement process as an allocation process rather than a recruitment process. The hosts that accepted the process as part of their partnership with the university were happy to accept a lower preference cadet. The hosts that viewed their cadet as part of their workforce planning felt that they should have been allowed to recruit their first choice.

Hosts' responses to not being allocated a cadet were also mixed, with the number of applicants being the main distinguishing feature. The hosts that had fewest applicants were those that had historical issues attracting engineers to their organisation; as such they seemed somewhat reconciled to the possibility that this process would also not lead to a placement outcome. Hosts that had a full shortlist to interview, but were then subsequently left without a cadet as a result of the algorithm, were the most aggrieved, and this has led to ongoing relationship management issues for the university.

The emergent theme of the matching process is that the overall unhappiness is minimised, but that the mechanism for doing so is to consolidate it and give it to a select few hosts or cadets. Those who are selected by the algorithm to receive the unhappiness are indeed unhappy; and while intellectually they may understand that this unhappiness may be structural and unavoidable in nature, they would nonetheless prefer that someone else carry the burden. While the utilitarian nature of the process does not serve to console partners in the discussion, it has nonetheless been useful for staff in the university as they have communicated with the hosts. Staff know that the final allocation minimises the total amount of unhappiness overall, and that the only way to make a particular partner less unhappy is to move their unhappiness to a different partner; but doing so moves away from the optimal allocation, and creates even more unhappiness overall, and that additional unhappiness will have to be distributed to third and subsequent partners as the ripples of the change play out. This knowledge is a powerful reassurance while dealing with disgruntled partners.

It is worth noting that all hosts who were allocated a non-1st choice preference in the 2017 round have all elected to retain those cadets into the 2018 round, placing them directly rather than returning to the competitive marketplace.

Conclusion

In general, an objective utilitarian method of fairly allocating cadets to placements has been implemented, allowing us to manage the diversity of discipline and location preferences of the cadets while balancing the needs and preferences of the hosts. The algorithm is robust with regard to its parameters, and identifies the optimum matching that minimises the overall unhappiness levels of the cadets and hosts in the program. Most cadets and hosts are initially satisfied with the allocations provided by the algorithm; in most instances initially dissatisfaction has subsided over the full course of the placement.

The most powerful contribution of the matching algorithm is the objective certainty amongst the CSU Engineering team that the allocation is in fact optimal, and not the result of subjective biases in the academic team. When dealing with upset hosts, it is reassuring to know that while there are other allocations that would reduce their individual unhappiness, these allocations would simply move that unhappiness (and more besides) onto other hosts in the program.

It is impossible to eliminate unhappiness entirely from the allocation process. The knowledge that our process has treated all of our partners fairly allows us to remain dispassionate in our communications, and allows our disgruntled partners to remain / return after their initial emotion has passed. In doing so we are able to maintain our shared focus on educating future engineering professionals.

Acknowledgements

The authors thank the host organisations and cadet engineers without whom this program would not exist. The authors also gratefully acknowledge Loren Edmundson's contribution with her hard work in dealing with all of the host organisations and guiding them through the process.

References

Graduate Careers Australia. (2015). *Graduate Outlook 2014: Employers' Perspectives on Graduate Recruitment in Australia*. Retrieved from Melbourne:

Male, S., & King, R. (2013). *Summary of best practice guidelines for engineering faculties on effective industry engagement in Australian engineering degrees*. Retrieved from https://www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/industry_engagement_forengineering_-_summary_guidelines_as_at_aaee_conference.pdf

Morgan, J. R., & Lindsay, E. D. (2015). *The CSU Engineering Model*. Paper presented at the the Australasian Association for Engineering Education Annual Conference, Torquay, VIC, Australia.