Uncovering the Selection Criteria of HEIs when Choosing Timetabling Applications using ERP as a Reference

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ABSTRACT
Higher education institutions (HEIs) are under constant competitive pressure [10] which results in an increased importance of efficiency and effectiveness in the organisation, which in turn increases the importance of selecting the right timetabling application. Timetabling applications are increasingly considered to be at the heart of the HE organisation. They have impact on the schedules of teachers, students and staff [15] and they thus have a direct cause on the effectiveness and efficiency of them. The selection of timetabling applications fitted for the organisation is an essential first step for managing and controlling the schedules. Identifying and quantifying the categories of selection criteria presently used by HEIs to select timetabling applications is the first step in improving this selection process, leading to a better understanding of ways to control effectiveness and efficiency in education. This paper evaluates public tenders put forward in several North-Western European countries from 2003 up to now (2016), using the model for ERP system selection as proposed by Wei et al [17] as a reference. Comparison with ERP models is key for identifying and measuring the selection criteria used by HEIs in their selection process of timetabling applications in a structured and consistent way. Categories of selection criteria and their corresponding weights in the selection process are discovered. It is, for example, found that of the identified categories of selection criteria the category implementation time is weighted the lowest and this provides the biggest opportunity for improvement. Also, a first discussion is started on the division of these categories into subcategories. This paper contributes to the discussion of the way timetabling selection criteria are used in HEIs.

Keywords
Public tender, procurement, tendering, Higher education institutions, HEI, timetabling, timetabling applications, selection criteria, ERP, Enterprise Resource Planning, system selection.

1. INTRODUCTION
Timetabling applications in Higher Education Institutions (HEIs) are essential for the organisation to have more or less control over the effective and efficient deployment of their teachers, staff and other resources [15]. HEIs are currently in a constant competition on both a national and an international level [10]. Therefore, HEIs have an increasing need to select the right software to gain and maintain competitive advantage. This results, for instance, in an increasing demand for flexibility meaning more student- or individual-central timetabling practices [5][14].

Timetabling applications are concerned with “the allocation of given resources to specific objects being placed in space and time, in such a way as to satisfy as nearly as possible a set of desirable objectives, subjected to constraints” [18]. As timetabling is a NP-Complete problem [2][12], no one perfect solution can be found. Timetabling therefore aims to construct the best possible answer to the problem of timetabling.

During the International Timetabling Competition in 2007, organised by Paechter and Gambardella of the European Metaheuristics Network, three categories of university timetabling were distinguished: Examination Timetabling, Post-Enrolment-Based Course Timetabling (PE-CTT) and Curriculum-Based Course Timetabling (CB-CTT)[8]. We therefore consider applications dealing with one or more of these categories to be timetabling applications.

Timetabling involves, among other things, satisfying a set of objectives subjected to constraints [18]. Burke et al. [3] defines two kind of constraints, namely hard and soft constraints. A timetable is considered not a feasible solution when any hard constraints are broken whereas a timetable can be a feasible solution when some soft constraints are broken, which is usually the case.

Taking this in account, it is fair to conclude that the process of timetabling is one of many complexities which also has a key role in HEIs. Selecting a suitable timetabling application to support this process can therefore have real influence on the efficiency and effectiveness of the HEI. A search in Scopus reveals that little research has been done on the subject of the selection process for these software applications (graph 1). The following search query was used:

(TITLE-ABS-KEY"software selection") AND TITLE-ABS-KEY("higher education") AND (LIMIT-TO(SUBJAREA,"COMP") OR LIMIT-TO(SUBJAREA, "MUS") OR LIMIT-TO(SUBJAREA, "DECP") OR LIMIT-TO(SUBJAREA, "ECON") )
HEIs re-evaluate their current timetabling software every so often and make a decision on whether they should keep it as is, or whether they should modify or replace it. A public tender is issued when the decision is made to acquire a new application and the value of the contract exceeds the threshold that is laid down in EU Regulations. The threshold for HEIs is established in 2014 to be €209,000 [13]. Meaning that HEIs will often have to issue a tender when acquiring a new application. At the end of such a tender process a contract is awarded to the vendor with the application that the concerned HEI considers to be the best choice.

Research in the selection criteria used in the timetabling selection process by HEIs will be a first step in improving timetabling application selection and consequently towards improving the competitiveness of the HEI as a whole.

The field of manufacturing resource planning (MRP II) is concerned with the resource planning of a manufacturer. ERP has its roots in MRP but has an even more central position and influence on enterprise wide system of an organisation [4]. Both ERP and timetabling systems are central systems with great influence on almost all aspects of an organisation. The field of ERP research is a much more matured field of research than the field of timetabling in HEI and thus it will be used as a reference to evaluate the collected tenders. Insight in the selection criteria used by HEIs in selecting timetabling applications can be achieved in a systematic way by comparing the matured and similar field of ERP system selection with the found tenders for selecting a timetabling application.

1.1 Research questions

This paper identifies the categories of selection criteria used by HEIs in selecting timetabling applications. It determines which categories are and which factors are not considered by HEIs in the selection of timetabling applications. In addition, the use and weight of these categories are also determined. This is done by evaluating public tenders using ERP as a reference, resulting in the following research question and sub-questions:

What can be learnt about current practices in timetabling application selection issued by HEIs by comparing tenders to ERP system selection theory?

- What categories of selection criteria in the ERP systems selection process are (not) considered in tenders for timetabling software issued by HEIs?
- How are categories of selection criteria in the ERP systems selection process weighted differently than in tenders for timetabling software issued by HEIs?

1.2 Structure of this paper

Chapter two describes the approach we use in this paper. Following this, in chapter three we select the model which will be used for evaluating the public tenders. Chapter four presents the analysis of the dataset containing the tenders and selection criteria extracted from these tenders. We conclude this paper in chapters five and six with a discussion of the findings and a discussion of future work.

2. RESEARCH METHOD

In this chapter we discuss the research method, which in our case consists of three phases as shown in figure 1.

2.1 Phase 1: Gathering of selection criteria and finding a model

Phase one is concerned with the gathering of the information that is used. The public tenders will be gathered and their selection criteria extracted. In this phase we will also find a model for selecting software applications based on ERP literature including categories and importance of these categories to one another.

In this research we only consider tenders which comply to the following rules:

- The tender is purely for a timetabling application;
- The tender is issued by an HEI located in North-West region of Europe (Benelux, Germany, Denmark, Sweden, Norway, UK and Ireland);
- Accompanying tender documents are available.

Tenders are gathered by searching the “online version of the ‘Supplement to the Official Journal’ of the EU, dedicated to European public procurement” [1]: ted.europe.eu. The selection criteria are then extracted from these tenders, in preparation of phase two.

As discussed before, timetabling applications are considered to be similar to ERP. We will therefore use literature in the field of ERP to establish the model consisting of a set of categories having influence on system selection with corresponding values of importance.

![Graph 1 - Count of papers found](image)

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As discussed before, timetabling applications are considered to be similar to ERP. We will therefore use literature in the field of ERP to establish the model consisting of a set of categories having influence on system selection with corresponding values of importance.
2.2 Phase 2: Comparing the model with public tenders

Subsequently, in phase two, the previously found software selection model is used to categorise the extracted selection criteria by use of labelling. The labels used are those of the categories provided in the software selection model. Selection criteria which cannot be allocated to one of the categories in the model would suggest an incomplete model. At least in pertaining to selection of timetabling software in HEIs. Such selection criteria will be grouped in a miscellaneous category which can later be further analysed to determine possibly new categories.

After this, second level labelling is done by using the subcategories of the ERP software selection model. Selection criteria that did not fit any of the ERP sub-categories in its category will again be collected in a miscellaneous category. Labelling without any reference is done if no subcategories were given by the ERP model.

2.3 Phase 3: Analysis of the categorised selection criteria

The categorised selection criteria are analysed to determine to which extend the categories of the ERP software selection model can be found in the tenders. Possible categories present in the tenders which are not present in the ERP software selection can be found by evaluating the miscellaneous category. In addition, the weight of the categories relative to each other will be analysed and compared to ERP.

It is further possible to analyse the sub-criteria as the selection criteria have also been labelled in a second level. Possible subcategories of the earlier found categories can be identified and discussed.

3. ERP SYSTEM SELECTION MODEL

The ERP based model used is the model for selecting the most appropriate ERP system as described by Wei et al. [17], which is a well-established model with many citations (see table 1). This model is found by searching for 'ERP system selection'. Moreover, this model covers the selection criteria for ERP system selection as used in other literature such as Van Everdingen et al. [7], Verville and Halingten [16], Kumar et al. [11] and Hecht [9].

Table 1. Citations of Wei et al. [17].

<table>
<thead>
<tr>
<th>Archive</th>
<th>Citations</th>
<th>Date of count taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Scholar</td>
<td>513</td>
<td>18-04-2016</td>
</tr>
<tr>
<td>Scopus</td>
<td>268</td>
<td>25-03-2016</td>
</tr>
<tr>
<td>Web of Science</td>
<td>158</td>
<td>18-04-2016</td>
</tr>
</tbody>
</table>

The model used for evaluating the public tenders consists of two parts, see figure 2. The first part encompasses selection categories describing the most appropriate system while the second part encompasses selection categories describing the most appropriate vendor. These are further elaborated in chapters 3.1 and 3.2 respectively. This elaboration is added in order to be able to categorise the selection criteria in phase 2 in a consistent manner. The ERP system selection model of Wei et al. [17] did only provide more information on the categories than the titles of these categories and their subcategories. The elaboration is thus our own interpretation guided by these titles.

Figure 2 - System selection model by Wei et al. [17]

3.1 Most appropriate system

<table>
<thead>
<tr>
<th>System category</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Costs</td>
<td>12%</td>
</tr>
<tr>
<td>2: Implementation time</td>
<td>15%</td>
</tr>
<tr>
<td>3: Functionality</td>
<td>41%</td>
</tr>
<tr>
<td>4: User-friendliness</td>
<td>04%</td>
</tr>
<tr>
<td>5: Flexibility</td>
<td>05%</td>
</tr>
<tr>
<td>6: Reliability</td>
<td>24%</td>
</tr>
</tbody>
</table>

The system categories provided by the ERP system selection model of Wei et al. [17] are costs, flexibility, functionality, implementation time, reliability and user friendliness. All of which were given a weight portraying their importance within this set of categories, see table 2.

1: Minimising total cost

This category encompasses factors contributing to the costs of the system. The model makes a distinction between the subcategories price, maintenance costs, infrastructure costs and consulting expenses. We considered price to be the direct cost of gaining the right to use it. Maintenance costs are the costs brought about by repairs and fixes to keep the system able to perform as expected. Not to be confused with infrastructure costs which are the costs of the support systems which enable the software to run. Consulting expenses are the costs of consultancy.
2: Minimising implementation time
This category encompasses factors contributing to the implementation time of the system. It encompasses criteria related to the planning and timeframe of implementation the system.

3: Having complete functionality
This category encompasses factors contributing to ensuring complete functionality of the system. The model makes a distinction between the subcategories module completion, function fitness and security. Module completion criteria ensure the systems contains all modules the HEI expects it to have. Function fitness then ensures that the implementation is fitting within the current timetabling process. The criterion that a system can import student data is therefore a module completion criterion while the criterion that the system should be able to handle at least 40,000 students is a function fitness criterion. Security contains criteria which ensure the security of the data used and produced in the system in terms of both illegal external access as illegal internal access.

4: Having user-friendly interface and operations
This category encompasses factors contributing to the user-friendliness of the interface and operations of the system. The model makes a distinction between the subcategories ease of operation and ease of learning. Ease of operation ensures that operations within the system can be done in a sufficiently easy and quick manner. Ease of learning however covers the effort (new) users of the system have to put in to learning to operate the system.

5: Having excellent system flexibility
This category encompasses all the factors contributing to the flexibility of the system. The model makes a distinction between the subcategories ease of integration, upgrade ability and ease of in-house development. Integration covers the connectivity of the system to other (already) in place systems. Upgrade ability deals with the ease of upgrading like the ability to develop and implement upgrades. This while ease of in-house development makes sure the system can also be upgraded and adapted by the HEI itself.

6: Having high system reliability
This category encompasses all the factors contributing to the reliability of the system. The model makes a distinction between stability and recovery ability. Stability covers the criteria ensuring that the system will not stop functioning when faced with different internal and external influences. This in contrary to recovery ability which covers the criteria that will ensure the system being able to recover to a functioning state after it did stop functioning.

3.2 Best vendor
The vendor categories provided by the ERP system selection model of Wei et al. [17] are reputation, technical capability, and service. All of which were given a weight portraying their importance within this set of categories, see table 3.

<table>
<thead>
<tr>
<th>Vendor category</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>7: Reputation</td>
<td>08%</td>
</tr>
<tr>
<td>8: Technical capability</td>
<td>64%</td>
</tr>
<tr>
<td>9: Service</td>
<td>28%</td>
</tr>
</tbody>
</table>

7: Reputation
This category encompasses all the factors contributing to the reputation of the vendor. The model makes a distinction between the subcategories scale of vendor, financial condition and market share. Scale of vendor criteria are concerned with the size of the vendor. Financial condition criteria are concerned with the financial situation of the vendor. Criteria ensuring, for instance, a certain amount of other users of the systems are bundled under market share criteria.

8: Technical capability
This category encompasses all the factors contributing to the perceived technical capabilities of the vendor. The model makes a distinction between the subcategories Research and Development ability, technical support capability and implementation ability. The ability of the vendor to research and develop new technologies are Research and Development criteria. Technical support capability criteria are concerned with the ability of the vendor to deal with technical difficulties while implementation ability criteria are concerned with the ability of the vendor to implement requested and or designed functionality.

9: Service
This category encompasses all the factors contributing to the vendor providing ongoing services. The model makes a distinction between the subcategories warranties, consultant services, training services and service speed. Warranty criteria are concerned with the warranties the vendor provides in case the system or implementation process don’t meet the promised requirements. Consultant services covers the criteria ensuring the number of consultant and experience of the consultants working at the vendor. Criteria concerned with the amount of training time and the quality of the training lessons are bundled under training service criteria. Service speed is concerned with the required response time of the different services.

4. ANALYSIS
4.1 Origin of the researched tenders
A set of eighteen tenders were collected for this research. This set is comprised of tenders originating from: The Netherlands, Belgium, Great Britain, Ireland, and Norway (As shown in figure 3). They are published in a period from 2003 up to and including 2016.

Figure 3 - Map of tender origins
The process of extracting selection criteria from the tenders was difficult. Mostly because the tenders were all written differently. They seemed to lack use of any kind of generally accepted framework. In some tenders the requirements were given as one-line criteria without any context as for why these criteria were demanded. While other tenders described the desired process the system has to support without any clearly distinguished criteria.

4.2 Gathered set of selection criteria
A first indicator for the quality of a tender is the amount of different categories of selection criteria it addresses. Of the tenders evaluated, one outlier only addressed 2 categories. The remaining 17 address on average 7.4 of the 9 categories, ranging from 5 up to and including 9 of 9 categories (graph 2). This outlier is therefore extracted from the dataset as suspected to be missing documentation. The remaining dataset consisting of 2,190 selection criteria is divided into 9 different categories, as described in section 3. Also 46 selection criteria are placed in the miscellaneous category. Accounting for an average of 132 selection criteria per tender for in total seventeen tenders.

Graph 2 - Count of tenders vs. Categories in tender

4.3 Miscellaneous category
Further evaluation by labelling of the criteria in the miscellaneous category did not result in possible new categories for system selection as most of the criteria were related to tender process itself. In addition, the miscellaneous category contains only 46 criteria which in comparison to dataset of 2,190 selection criteria makes this category very small in size (2.1%). This suggests that current practices do not use selection criteria of categories not yet known to ERP system selection theory.

4.4 Count of unique tenders per category
As shown in graph 3, all tenders have selection criteria in the categories flexibility, functionality and user Friendliness. The category reliability is similar to these categories with 94% of the tenders having selection criteria in this category. These four categories are thus identified to be a (mostly) consistent part of timetabling software selection tenders.

Reputation and Service are mentioned in 82% of the tenders and technical capability and costs are mentioned in 76% of the tenders. Most tenders thus have selection criteria of these criteria although there is a notable amount of tenders who have not. This suggests that these tenders have room for improvement by adding selection criteria in these not yet covered categories.

The last category to be discussed is implementation time. The least amount of tenders, namely 59%, contained selection criteria of this category. Thus, of all 17 tenders, the category implementation time seems to offer the most potential for improvement.

4.5 Relative importance of the categories
The priority of items mentioned by a speaker can be measured by, among other things, how often these items are mentioned [6]. The difference in the amount of selection criteria between categories is therefore used as an indicator for their relative weight. With this in mind, a comparison can be made between the weight of categories given in public tenders and the weight of categories as given in the ERP model, as given in chapter 3. This results in graphs 4 and 5.

Graph 4 - System categories, comparison of weight
The most notable differences are those of the relative count of criteria is less than half or more than double the weight given by ERP. This means that the following system categories are notable: flexibility, implementation time, reliability and user friendliness. Flexibility and user friendliness are valued to be less important by the ERP model than it is valued by tenders for timetabling software issued by HEIs. Implementation time and reliability however are valued to be more important by the ERP model than by tenders for timetabling software issued by HEIs.

Reputation and technical capability are the most notable categories in vendor factors. Reputation is valued as less important by the ERP model than it is valued by tenders for timetabling software issued by HEIs. Technical capability however is valued as more important by the ERP model than by tenders for timetabling software issued by HEIs.

With further analysis it is possible to analyse the sub-criteria because the selection criteria have also been labelled in a second level. The suggestion for subcategories as given by the ERP model were used in this labelling process. This is the basis of a discussion around the proposed sub-categories of the earlier found categories. The category implementation time will however be excluded from this process as the ERP model does not provide sub-categories for it. The rest of this section will discuss our findings of the analysis.

As shown in graph 6, the category costs is comprised of the labels consultancy, infrastructure, maintenance, price, and miscellaneous. Infrastructure criteria are a negligible part of costs criteria in tenders. Price criteria are most frequently mentioned and make 36% of the total costs criteria. The consultancy, maintenance and miscellaneous subcategories all make circa 20% of the costs criteria. The fact that the miscellaneous subcategory is that sizable could indicate possible missing subcategories.

The category reliability is comprised of the labels recovery ability, stability, and miscellaneous. These subcategories are all fairly equivalent to each other. The miscellaneous subcategory could therefore indicate missing subcategories.

The category reputation is comprised of the labels financial condition, market share, scale of vendor and miscellaneous. Financial condition and market share respectively make up 23% and 22% of the criteria in the reputation category. Scale of vendor is a smaller subcategory with 14%. The miscellaneous category however contributes to 41% of the reputation criteria, indicating possible missing sub-categories.

The category service is comprised of the labels consultant services, training service, warranties and miscellaneous. By far the biggest subcategory in the service category is, with 49%, consultant services. This is a possible indication that this subcategory could be split up. The categories speed of service, training services and warranties all make out circa 11%. The miscellaneous category makes out 17% of the service category. This indicates possible missing sub-categories.

The category technical capability is comprised of the labels implementation capability, research and development, technical support and miscellaneous. Implementation capability and research and development make for respectively 40% and 29% of the selection criteria. Technical support is with 9% the smallest subcategory. The miscellaneous category makes 22% of the criteria, indicating a possible missing subcategory.
The category user friendliness is comprised of the labels ease of learning, ease of operation and miscellaneous. Ease of operation is with 92% by far the biggest subcategory of user Friendliness. This indicates that this subcategory might be eligible to be split up in other categories. Easy of learning and miscellaneous both make 4% of the user Friendliness criteria.

5. CONCLUSION

Tenders are collected from The Netherlands, Belgium, Great Britain, Ireland, and Norway. Extracting, categorising and analysing the selection criteria from these tenders produced several findings which can be summarised in the several bullet points. These first bullet points identify the different categories and subcategories of selection criteria and in doing so they answer the first research question:

- The ERP system selection model of Wei et al. [17] provides a suitable reference as no new categories of selection criteria had to be established to be able to label the selection criteria found in the tenders evaluated. Tenders evaluated address on average 7.4 of the 9 categories provided by the ERP software selection model.
- The flexibility, functionality, user friendliness and reliability selection criteria can be found in almost all tenders. While reputation, service, technical capability and costs selection criteria can be found in a considerably less amount of tenders, circa 80%. The implementation time selection criteria are however found in the least amount of tenders, circa 60%.

Overall, the tenders seemed to be of a reasonable level of completeness, with several categories of selection criteria identifiable in almost all researched tenders. However, there are several categories of selection criteria which are not yet optimally integrated in current timetabling application tender practices. The category implementation time provides the biggest opportunity for improvement. The following system categories were identified in descending order of the amount of tenders in which they have appeared: flexibility and functionality and user friendliness, reliability, costs and implementation time. Subsequently, the following vendor categories were identified, also in descending order of the amount of tenders in which they have appeared: service and reputation and technical capability.

Further also the weight of these categories are identified and in doing so research question two is also answered:

- The tenders put more weight on the system category flexibility and user friendliness and on the vendor category reputation than the model for ERP system of Wei et al. [17] does.
- The tenders put less weight on the system categories implementation time and reliability and on the vendor category technical capability than the model for ERP system of Wei et al. [17] does.

Timetabling application tenders of HEIs seem to have a relatively higher interest in the flexibility of the system and reputation of the vendor than would be expected from ERP literature. Flexibility could possibly be explained by the fact that the timetabling application often is one of the core systems in an HEI and that the system is often linked to multiple different databases, portals, etc. Reputation is however a category for which its higher weight is more difficult to explain. Timetabling tenders of HEIs seem to have less interest in the implementation time and the reliability of the system as well as the technical capability of the vendor than would be expected from ERP literature. Implementation time could be cause by the nature of the category, as often only few criteria are needed to cover its domain. This would however raise the question whether implementation time deserves to be a category on its own. The low interest in reliability and technical capability of the vendor is surprising, and cannot be explained to our knowledge. This however might indicate an opportunity for improvement of timetabling application tenders.

In addition, further analysis was done and the following is also found:

- The ERP model of Wei et al. [17] provides a set of subcategories per category to be used in evaluating systems. Several of these subcategories are however probably too general, namely: flexibility-integration, service-consultant service and user friendliness-ease of operation. Some subcategories were found too small, namely: costs-infrastructure and user friendliness-ease of learning. Also, indications were found for several categories where subcategories are missing, namely: costs, flexibility, reliability, reputation, service and technical capability.

This paper aimed to provide insight in the selection criteria used by HEIs to select timetabling applications. This can be the first step in improving this selection process, leading to a better understanding of ways to control effectiveness and efficiency in education. The paper therefore identified the different categories of selection criteria appearing in public tenders for timetabling applications in HEIs located in North-Western Europe. This was done by comparing these tenders with a well-established ERP software selection model. Besides this, this paper also provided some further insight in the weight of these categories in comparison to each other. In addition to this, a first critical view on possible subcategories was made.

6. FURTHER WORK

Several subcategories have been discussed in the conclusion. Further labelling of the dataset could provide a more thorough insight in the subcategories specific to tenders for timetabling application by HEIs. The scope of this research limited the findings however to indicating possible subcategories needing revision.

There is a big difference between the researched tenders. A generally accepted framework seems to be missing. If that is the case, constructing such a framework would provide a great opportunity to increase the efficiency and effectiveness of the timetabling application tender process within HEIs. A framework encompassing all different aspects of the tendering process including the selection criteria should be established. The findings of this paper would be a good starting point for such a framework.

7. ACKNOWLEDGMENTS

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8. REFERENCES


