International Journal of Industrial Engineering and Management (IJIEM), Vol. 9 No 1, 2018, pp. 43-51
Available online at www.iim.ftn.uns.ac.rs/ijiem_journal.php
ISSN 2217-2661

UDC 005.96

An Analytic Hierarchy Process Based Approach for Indirect Labour Cost Allocation

Cristina Ponsiglione
Department of Industrial Engineering, University of Naples Federico II, Piazzale Tecchio, 80 - 80125 Naples, Italy, ponsigli@unina.it

Maria Elena Nenni
Department of Industrial Engineering, University of Naples Federico II, Piazzale Tecchio, 80 - 80125 Naples, Italy, menenni@unina.it

Gianfranco Castellano
MBDA Italia SpA, Via Giulio Cesare, 105 – 80070 Naples, Italy, gianfranco.castellano@mbda.it

Armando Molisso
MBDA Italia SpA, Via Giulio Cesare, 105 – 80070 Naples, Italy, armando.molisso@mbda.it

Received (04.09.2017.); Revised (20.12.2017.); Accepted (17.01.2018.)

Abstract

This study aims at proposing a methodological approach supporting the allocation of indirect labour costs to different projects in complex multi-project environments. The purpose is to build a flexible methodology based on activity-based costing principles, which is suitable in all situations characterized by a high impact of indirect labour costs and a certain level of business complexity.
The proposed methodology is based on the application of an analytic hierarchy process (AHP) approach to create a multi criteria–based ranking of the projects. Indirect labour costs are then allocated proportionally to the obtained relative weights. The methodology has been tested in a multi project–based organization operating in the defence industry.
The results from the case study demonstrate that the proposed AHP-based approach can provide a method that takes into account the subjectivity and uniqueness of activities performed by humans. At the same time, the developed multi-criteria approach is flexible enough to adjust to the requirements of different management structures and to the changes in projects' portfolio.
The application of this approach is now limited to just one case study, but even if a multiple case study research strategy is desirable in the future, it doesn't seem to affect the robustness and generalizability of the methodology.

Key words: *Multipla Criteria Analysis; Human Resource Planning; Activity-based costing; Analytical hierarchy process; Multi-projects environment.*

1. INTRODUCTION

There is abundant evidence of the distortion produced by the apportionment of overhead costs on the basis of production resources' volumes in the management accounting and the strategic management literature [1-5]. Starting from the end of '80s, activity-based costing (ABC) has been suggested as an innovative approach to overcome the limitations of traditional costing techniques [6, 7, 4] and a managerial tool that can positively impact profitability and firm value [8-10]. More recently, the time-driven activity-based costing approach (TDABC) [11] has been proposed as a more powerful cost accounting method that solves some implementation difficulties related to the empirical application of ABC. TDABC reduces the complexity arising in the definition of an ABC model by requiring only two kinds of information: the time needed to perform an activity and the cost of supplying capacity per unit. The time variable becomes central to the process of TDABC model estimation and to the process of cost driver definition.

This study is motivated by the general need for supporting the accurate allocation of indirect labour costs to different projects as this process becomes intensely challenging in a complex multi-project environment.

According to [12], in such a context, different projects, each with a different scope, timeline and its own complexity, are managed in parallel sharing resources.

Human resources are shared as well and are often engaged in supporting activities, such as planning, procurement or supply chain management, that are only indirectly linked to projects. This is an incisive way for a company to share expertise and to transfer knowledge between different projects. However, it makes the labour cost allocation process more complicated because of both following factors:

1. The interactions and interdependencies between projects [13], which prevent the setting of specific boundaries in supporting activities.
2. The human factor, which usually increases the level of uncertainty [14] arising from the following aspects:
   - Subjectivity – carrying out a limited analysis of the processes involved in the activity;
   - Uniqueness – implicating the lack of historical data about drivers usually involved in the apportionment process;
   - Complexity – being evaluated in terms of the number of influencing factors and inter-dependencies between these factors.

Based on the concerns mentioned above and on the difficulty in applying a standard ABC technique, the basic idea of this study was to develop a multi criteria–based ranking of the projects using an analytic hierarchy process (AHP) approach and then to distribute the indirect labour effort to the projects in proportion to the relative weights obtained by the application of the AHP. In the development of the AHP model and of the related decision hierarchy, the final goal of allocating indirect labour costs to projects was taken into account and an activity-based logic was used to define the relationships among the levels of the hierarchy. The distribution of the effort of indirect personnel was the basis for calculating the indirect labour costs associated with each project.

In the study, the application of the methodology is demonstrated through the MBDA case. The company is the world leader in designing and producing missile systems. It is a representative example of a complex multi-project environment basically because its core business concerns complex systems integration using advanced technologies and a wider range of technical competencies.

Specifically, the case study concerns the Italian division of the MBDA which, in the last three years, has been involved in a change in its management accounting processes. In MBDA, Italy, the indirect labour costs of some typologies of workers operating in supporting activities were previously attributed to production cost centres using cost drivers based on volumes.

This approach was producing an evident distortion in the evaluation of the efficiency of production cost centres and of the entire Italian division of the MBDA with respect to the other geographical divisions that used different and more advanced approaches. In fact, the parameter of direct production cost per hour of projects increased after the attribution of indirect labour costs of supporting professional roles to the production cost departments.

To overcome this problem, the top management of MBDA Italy decided to define a suitable methodology in order to transform the indirect labour costs generated in supporting activities into direct costs to be directly attributed to the different projects carried out parallel to each other. The methodology proposed in this paper has been developed to cope with this challenge and is based on the following assumptions:

- The application of ABC and TDABC would have implied a radical change in the management accounting system of the Italian division of the company and a need for frequent changes in the ABC model due to the changes in projects' portfolios over time. This fact determined the choice of researchers involved in the case study research to adopt the approach of activities and of time-based drivers to build a method to assess the effort of professional roles involved in the analysis, without applying all the steps of ABC or of TDABC;
- Due to the lack of historical data and the characteristics of the multi-project context under investigation, a multi-criteria approach was selected as the most suitable method to allocate the efforts of indirect professional workers to simultaneous projects.

The paper is structured as follows: after Section 2, which presents the state of the art of workforce assignment methods, Section 3 is devoted to explaining the proposed methodological approach step by step. In Section 4, the approach is applied to a case study and the results are illustrated. In Section 5, a sensitivity analysis is developed and performed for the case study. The concluding section provides some final remarks.

2. LITERATURE REVIEW – THE PROBLEM OF WORKFORCE ALLOCATION

As the focus of the research is on estimating the efforts required by each project, the issue is also seen as a workforce allocation (WA) problem. There are various contributions on this topic; the authors of this study adopted the critical review from Saadat et al. [15] as a starting point. Then, the literature was classified into two streams: the approach used to deal with the issue and the context of application.

Regarding the approach used to solve the problem, WA is often seen as an extension of conventional scheduling problems [16]. According to this vision, it is possible to find comprehensive reviews of WA approaches in [17, 18], who both highlight the use of mathematics to construct appropriate models to address the WA problem [19-21]. Another line of research concerns the need to deal with multi-criteria objectives, and it sees the development of solutions based on artificial intelligence [22, 23].

Many authors have moved the focus to the different factors affecting the problem. Some researchers thus examine WA optimisation under deterministic conditions [24, 25], but other studies assess the stochastic nature

of problems involving issues such as learning curves and turnovers [26, 27]. However, a major challenge in WA is the occurrence of changes and, more particularly, of disturbances such as labour unavailability or demand fluctuation [15].
Regarding the application context, examples of WA occur in many areas: healthcare [28, 29], manufacturing context [30, 31] as well as in service one [32, 33], public transportation [34] and construction [35].
Coming to the multi-project context, [36] state that a multi-project situation causes problems in the allocation of scarce resources to a diversified project portfolio and the solution provided by the researchers in their study was flexible resource planning. Also [37] point out that in project-oriented companies, the allocation method needs to be flexible because of a fast-changing project portfolio. [38] have introduced a fuzzy optimization of labour allocation through genetic algorithms, and Wu (2007) has discussed a fuzzy linear programming approach for manpower allocation among projects within the matrix organization. Both researches are mostly oriented to minimize cost, leaving aside many other angles on the issue such as quality and uniqueness of human-performed activities or the projects' interactions.
Finally, the study that has pursued an objective more like that of this one has been conducted by [19]. The model addresses the challenges of the identification and quantification of indirect jobs but uses a non-parametric frontier approach based on historical data. Unfortunately, as each project is unique, historical data are often not available or are insufficiently reliable.
In conclusion, research in this field is still limited and there is room for improvement as existing models are unable to deal with the specific characteristics depicted above for supporting activities in a complex multi-project environment.
The proposed methodological approach aims at providing a framework that is suitable for the following:

- Capturing interdependencies and interactions between projects through ranking – instead of examining them separately – and by adopting an activity-based perspective;
- Dealing with the projects' complexity through a multi-criteria approach;
- Considering the subjectivity and uniqueness of human-performed activities by using AHP to collect qualitative data from experts;
- Managing uncertainty through a procedure based on the Spearman's Footrule method to perform a sensitivity analysis.

2.1 **Methodological approach**

The Analytic Hierarchy Process (AHP) is a decision-making method, which breaks down a complex problem into a multi-level hierarchical structure of objectives, criteria, sub-criteria and alternatives [39].
The final goal of AHP is to derive a priority scale by assigning weights to tested elements. Once the hierarchy has been constructed, the decision-maker calculates the relative importance (weight) of each element at each level (criteria, sub-criteria and alternatives) by pairwise comparisons. Eventually, a sensitivity analysis is hopefully carried out [40].
AHP has received wide attention in various fields [41-44]. In this paper, the AHP is applied to calculate a ranking of different projects carried out simultaneously in a complex multi-project organizational environment. Using relative importance as the coefficient, the methodology can allocate indirect workforce effort and then its cost to each project. The basic assumption for the model is that the total indirect workforce effort and its cost are both given.
Consequently, there isn't any aim at optimizing workforce or minimizing cost but rather at calculating how much cost and effort are supposed to be absorbed by each project in the portfolio.
As shown in Figure 1, the methodological approach has been structured into five main steps along with a preliminary one. As different indirect job roles can be employed in a project and the proposed methodology engages with a single one at one time, the procedure must be repeated as many times as the number of job roles.

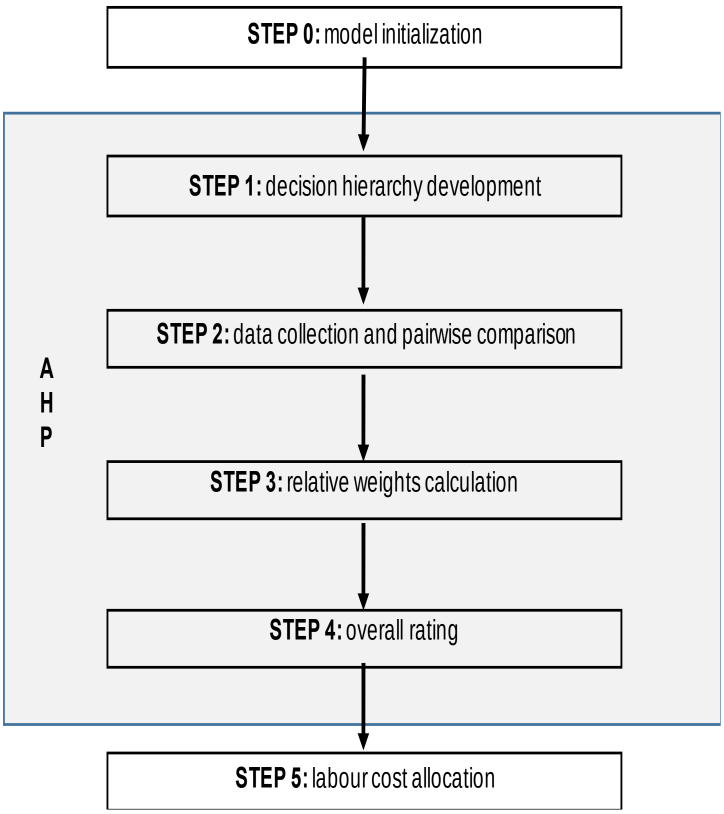

Figure 1. The proposed methodological approach.

STEP 0 – Initialization

The initialization of the methodology consists in selecting the indirect job roles whose costs have to be allocated to the projects. Then, prior knowledge, if it does not already exist, should be developed on their

specific contribution to the projects from an activity-based perspective. This step can be implemented by a mapping process.
Obtained knowledge should be hierarchically organized in activities that each professional role should perform and in drivers describing their consumption in terms of projects. Drivers are identified during the mapping phase as factors affecting the effort required from the activities.

STEP 1 – Decision hierarchy development

According to the AHP methodology, in this step the problem is broken down into elements, which are grouped on different levels to form a chain of hierarchy. The process of organizing objectives and elements in a hierarchy is aimed at two purposes: (i) To provide an overall view of the complex relationship inherent in the situation, and (ii) To help decision makers assess whether the issues in each level are of the same order of magnitude so that the homogeneity in comparison can be preserved.
The developed hierarchy consists of at least five levels. At the highest level of the hierarchy is the overall goal of estimating the effort for the job role under consideration. Activities performed and coming from the previous step form the first level, which can then be developed into more sub-criteria levels, according to the level of detail in the process mapping. The following sub-criteria level is occupied by the drivers, which represent the main factors affecting the duration of the relative activity in the upper level. The last sub-criteria level is occupied by the degrees of intensity at which the drivers can occur. This approach reflects the “absolute measurement” approach that is one of possibilities offered by the application of the AHP. At the level of the alternatives (the last one), projects in which the job role is involved are reported.

STEP 2 – Data collection from the selection panel and pairwise comparisons

The prioritization procedure is aimed at determining the relative importance of the elements within each level. In each level, the elements are compared pairwise according to their influence and based on the specified element in the higher level. A selected panel of experts performs this procedure. Their subjective judgment can then be converted to a numerical value using the fundamental scale of the AHP [45].

STEP 3 – Relative weights calculation

In this step, data are translated into the relative weights on the basis of Saaty’s Eigenvector procedure [45]. At this step, the consistency of the data is also investigated by determining the consistency ratio (CR) for all matrices. If the CR value is larger than 0.10, the comparisons should be reviewed [46].

STEP 4 – Overall ranking

This step concerns an overall ranking for all the projects with respect to the goal of estimating the efforts. Each project is separately evaluated on each driver (score) and an overall priority for each project is then obtained by a hierarchical composition procedure.
The overall ranking is finally calculated by normalizing the vector of overall priorities.

STEP 5 – Labour cost allocation

The effort of the job role under consideration is estimated by splitting the working hours among projects on an annual basis and according to the overall ranking. The labour cost is thus allocated by just multiplying the effort and the hourly cost.

3. APPLICATION TO A CASE STUDY

The proposed methodology has been tested in MBDA and here its application is reported for the role of “Production Controller” who is simultaneously involved in 8 projects.
The decision hierarchy is articulated at 5 levels: goal, activities, and drivers (as depicted in Table 1), intensity levels for each driver (for three levels labelled as “low”, “medium” and “high”), and finally, alternatives (projects).

Table 1. Hierarchical representation of the problem in the case study.

Goal	Activities	Drivers
Production Controller	Supporting Planning and Project Manufacturing Head (PMH)	Industrial Organization
		Production Volume
		Product Complexity
		Program Length
	Order Releasing	Production Volume
		Product Complexity
		Supplier Capability
		Production Capability
	Order/Product Management/Tracking	Industrial Organization
		Production Volume
		Product Complexity
		Supplier Capability
		Production Capability
	Not-Compliance Management	Industrial Organization
		Production Volume
		Product Complexity
	Data Recording	Production Volume
		Product Complexity
	Supporting and Corrective Actions	Production Volume
		Product Complexity

A panel of four experts performed the pairwise comparison in our case. Results have been aggregated by calculating the geometric mean for each set of values, and the whole AHP procedure has been implemented through the AHP Excel template by [47], as well as the CR calculation.
Relative weights for activities with respect to the goal are reported in Table 2.
The procedure has been reiterated in order to calculate drivers’ weight with respect to the activities. The

intensity levels for each driver have also been compared pairwise to capture the experts' opinions on their relative impact on the drivers' relevance.

Table 2. Activities weights with respect to the goal.

GOAL	1	2	3	4	5	6	W
Supporting Planning and PMH	-	0,54	0,21	1,46	1,32	3,41	0,64
Order Releasing	1,86	-	0,26	3,66	1,34	5,05	0,136
Order/Prod. Manag./ Tracking	4,79	3,87	-	6,09	2,76	6,51	0,26
Not-Compliance Manag.	0,69	0,27	0,16	-	1,59	1,86	0,039
Data Recording	0,76	0,75	0,36	0,63	-	1,19	0,474
Supporting & Corrective Actions	0,29	0,2	0,15	0,54	0,84	-	0,027

Finally, for each alternative (project) the more appropriate intensity level for each driver has been identified by experts, thus allowing the selection of the local weights of projects. The results for Project 2 are depicted in Table 3.

Table 3. Project 2 weights with respect to the drivers.

Activities	Drivers	Weight
Supporting Planning and Project Manufacturing Head (PMH)	Industrial Organization	0,637
	Production Volume	0,1991
	Product Complexity	0,7306
	Program Length	0,285
Order Releasing	Production Volume	0,1884
	Product Complexity	0,7306
	Supplier Capability	0,279
	Production Capability	0,1884
Order/Product Management/Tracking	Industrial Organization	0,7854
	Production Volume	0,1312
	Product Complexity	0,7928
	Supplier Capability	0,1884
	Production Capability	0,7306
Not-Compliance Management	Industrial Organization	0,297
	Production Volume	0,7306
	Product Complexity	0,1884
Data Recording	Production Volume	0,7306
	Product Complexity	0,297
Supporting and Corrective Actions	Production Volume	0,6738
	Product Complexity	

The total vector is obtained by multiplying the priority of each driver with the priority of each project associated with it and summing up the results.
The same procedure has been applied to evaluate the seven other projects. Results are reported in Table 4, where projects have also been sorted according to decreasing weight.

The overall weight vector expressed in percentage is obtained from the total vector by normalizing. The total annual effort is 4.800 hours to be allocated between eight projects as depicted in Table 5.
In the final stage, the annual cost is given by the hourly labour cost multiplied by the effort for a project. The data are not reported in this case for privacy.

Table 4. Project ranking.

N°	Project	Total	Overall Weight (%)
1	Project 2	3,507	30,12%
2	Project 1	3,386	29,08%
3	Project 6	1,104	9,48%
4	Project 8	1,069	9,18%
5	Project 7	0,802	6,89%
6	Project 3	0,600	5,15%
7	Project 5	0,600	5,15%
8	Project 4	0,575	4,94%

Table 5. Total effort allocation.

N°	Project	Total	Overall Weight (%)	Effort (hours/year)
1	Project 2	3,507	30,12%	1445,76
2	Project 1	3,386	29,08%	1395,84
3	Project 6	1,104	9,48%	455,04
4	Project 8	1,069	9,18%	440,64
5	Project 7	0,802	6,89%	330,72
6	Project 3	0,600	5,15%	247,20
7	Project 5	0,600	5,15%	247,20
8	Project 4	0,575	4,94%	237,12

It is important to outline that the methodology is characterized by a certain level of flexibility. In fact, the AHP application follows the "absolute method" in which the alternatives are not compared to each other directly, but are analysed in terms of the intensity levels of the drivers they exhibit.
This fact implies that, once the indirect job roles are analysed and the hierarchy of activities with drivers and intensity levels has been built, this hierarchy can also be applied in situations in which the list of projects has changed.
The hierarchy and the weights should be revised only when the content and the typologies of activities performed by a job role are affected by a relevant change.
Otherwise the result depends, in part, on the criteria used in the model. Therefore, the authors of this study have performed a sensitivity analysis.

4. SENSITIVITY ANALYSIS

While the general aim of sensitivity analysis (SA) is to provide insight into the robustness of a model's results, in this study, the authors have pursued an iterative SA-based procedure to refine and develop the WA model.
The goal then is to identify drivers that do not affect model robustness and remove them. The expected result is the reduction of the model complexity due to over-parameterization.

The main idea is to compare two different rankings of the same set by a procedure based on Spearman's Footrule [48]:

$$Fr^{|Z|}(\sigma_1, \sigma_2) = \sum_{i=1}^{|Z|} |\sigma_1(i)\text{-}\sigma_2(i)| \quad (1)$$

The following items are defined:

- Rankings A and B as domains of size k;
- i as an element of a domain;
- Z as the set of overlapping elements;
- σ_1 and σ_2 as two permutations on Z.

When the two rankings are identical, Fr|Z| is zero, and its maximum value is 1/2|Z|2 when |Z| is even, and 1/2(|Z|+1)•(|Z|-1) when |Z| is odd. If the result is divided by its maximum value, Fr|Z| will be between 0 and 1, independent of the size of the overlap; this is defined only for |Z|>1. Thus, the normalized Spearman's Footrule NFr for |Z|>1 is defined as follows [49]:

$$NFr = \frac{FR^{|Z|}}{maxFR^{|Z|}} \quad (2)$$

NFr attains the value 0 when A and B are identically ranked and the value 1 when they appear in opposite order.
The main idea is to compare two rankings, A and B, where A is the initial ranking and B is obtained after eliminating one or more parameters. If NFr attains the value 0, the two rankings are identical and then one can conclude that the eliminated parameters don't really affect the model. The procedure to remove parameters not affecting the model is articulated in two steps:

STEP 1 – The goal is to individuate drivers that don't affect the model. The tasks to be performed are as follows:

- A is selected as the initial ranking;
- One driver is eliminated (the choice of the driver doesn't affect the procedure);
- A new ranking, B, is developed;
- NFr is calculated: If NFr attains the value 0, the two rankings are identical and then one can conclude that the eliminated driver cannot be really affecting the model; otherwise the parameter affects the model and can't be removed;
- Step 1 is run until all drivers are analysed.

STEP 2 – The goal is to verify if parameters at Step 1 affect the model in case of simultaneous elimination. The tasks to be performed are as follows:

- A is selected as the initial ranking;
- Drivers at Step 1 are sorted by increasing the NFr;
- Drivers are eliminated simultaneously in an incremental way (initially the first two parameters, then the top three ones and so on);
- A new ranking, B, is developed at each stage of elimination;
- NFr is calculated: If NFr attains the value 0, the two rankings are identical and then we can conclude that the drivers eliminated until now don't really affect the model, even if eliminated simultaneously; else, it can be concluded that only the last driver we eliminated affects the model and we can't remove it;
- Step 2 is run until all drivers are analysed.

4.1 Application to the case study

Starting from the initial ranking in Table 4, each criterion used for the model has been analysed by performing Step 1 of sensitivity analysis.
As the first step, the industrial organization in supporting planning and project manufacturing head (PMH) was eliminated and the ranking was changed according to Table 6.

Table 6. New ranking of Projects.

N°	Project	Total	Difference between total weight	Difference between position in the ranking
1	Project 1	3,265	3,386-3,265=0,121	2-1=1
2	Project 2	3,208	3,507-3,208=0,299	1-2=1
3	Project 6	0,983	0,600-0,551=0,049	0
4	Project 8	0,948	0,575-0,526=0,049	0
5	Project 7	0,753	0,600-0,551=0,049	0
6	Project 3	0,551	1,104-0,983=0,121	0
7	Project 5	0,551	0,802-0,753=0,049	0
8	Project 4	0,526	1,069-0,948=0,121	0
Average Absolute Deviation			0,859	
Sperman index			2	
Normalized NFR			2/32=0,063	

Then NFr was estimated by calculating the following two values for each project:

- Difference between total weights;
- Difference between positions.

According to the methodology, in this case Z was equal to 8, then the following held true: FR|Z| = 1/2|Z|2 = 32. Results from Step 1 for each driver have been reported in Table 7.
From Table 7, it is possible to conclude that drivers 1, 9 and 14 surely affect the model; consequently, they

cannot be removed. For all the other drivers, Step 2 has been performed. Preliminarily, drivers have been sorted by increasing weight (Table 8).
By performing Step 2, we obtained an NFr attaining the value 0 by simultaneously eliminating drivers from 1 to 10. The incremental elimination of driver number 11 led to an NFr attaining the value 0.031. It meant that driver number 11 could not be removed from the model as we had just eliminated the other drivers.

Table 7. Results from Step 1.

N°	Drivers	NFr
1	Industrial Organization in Supporting Planning and Project Manufacturing Head (PMH)	0,063
2	Production Volume in Supporting Planning Support and PMH	0
3	Product Complexity in Supporting Planning and PMH	0
4	Program Length in Supporting Planning and PMH	0
5	Production Volume in Order Releasing	0
6	Product Complexity in Order Releasing	0
7	Supplier Capability in Order Releasing	0
8	Production Capability in Order Releasing	0
9	Industrial Organization in Order/Product Management/Tracking	0,063
10	Production Volume in Order/Product Management/Tracking	0
11	Product Complexity in Order/Product Management/Tracking	0
12	Supplier Capability in Order/Product Management/Tracking	0
13	Production Capability in Order/Product Management/Tracking	0
14	Industrial Organization in Not-Compliance Management	0,063
15	Production Volume in Not-Compliance Management	0
16	Product Complexity in Not-Compliance Management	0
17	Production Volume in Data Recording	0
18	Product Complexity in Data Recording	0
19	Production Volume in Supporting and Corrective Actions	0
20	Product Complexity in Supporting and Corrective Actions	0

Step 2 performed for drivers from 12 to 17 never resulted in an NFr attaining the value 0 again. Then we could not remove any other drivers from the model.
Finally, it is possible to conclude that the proposed model is robust and effective by using just 10 drivers out the initial 20. Such drivers are reported in Table 9. The sensitivity analysis led to a simplified model, using less drivers, and it showed the model robustness anyway. It has been possible to remove half of the initial number of drivers without any change in the ranking. As a further development, a longitudinal analysis may be interesting in order to understand the link between model setting and projects' portfolio changes.

Table 8. Drivers sorted by increasing weight.

N°	Drivers	Weight
1	Production Volume in Not-Compliance Management	0,0033
2	Program Length in Supporting Planning and PMH	0,0044
3	Production Volume in Supporting Planning and PMH	0,0083
4	Production Volume in Order Releasing	0,0089
5	Production Volume in Supporting and Corrective Actions	0,0093
6	Product Complexity in Supporting and Corrective Actions	0,0177
7	Product Complexity in Supporting Planning and PMH	0,0213
8	Supplier Capability in Order Releasing	0,0222
9	Product Complexity in Not-Compliance Management	0,0251
10	Production Capability in Order Releasing	0,0289
11	Production Capability in Order/Product Management/Tracking	0,0300
12	Product Complexity in Order Releasing	0,0760
13	Product Complexity in Order/Product Management/Tracking	0,1122
14	Production Volume in Data Recording	0,1452
15	Production Volume in Order/Product Management/Tracking	0,2600
16	Supplier Capability in Order/Product Management/Tracking	0,2600
17	Product Complexity in Data Recording	0,3288

Table 9. Drivers affecting the model.

N°	Drivers
1	Industrial Organization in Supporting Planning and PMH
2	Industrial Organization in Order/Product Management/Tracking
3	Industrial Organization in Not-Compliance Management
4	Production capability in Order/Product Management/Tracking
5	Product Complexity in Order Releasing
6	Product Complexity in Order/Product Management/Tracking
7	Production Volume in Data Recording
8	Production Volume in Order/Product Management/Tracking
9	Supplier Capability in Order/Product Management/Tracking
10	Product Complexity in Data Recording

5. CONCLUSION

The study provides a new approach for indirect labour cost allocation, which better fits the requirements of activities supporting complex projects. The proposed approach is also flexible to the changing needs of the organization due to a dynamic business environment. In fact, the findings of this study point to the need for considering many different drivers to allocate labour costs in case of indirect resources being shared among more complex projects. These drivers are not easy to standardise, rather, they should come from the management structure of the company.

The proposed methodology has been implemented in MBDA and it has won "One Star MBDA Innovation Award 2015" for "Best Business Practice".

The result from the case study demonstrates that the proposed AHP model can provide a method to estimate the share of the total effort absorbed by each project. AHP cost allocation model offers the flexibility to match the managerial experience and experts' judgement about projects' complexity with their specific measurable characteristics. Additionally, the evaluation is developed by comparing projects on the same basis, which assures a feasible solution.

From a managerial point of view, the proposed approach provides the company with a clear vision of the effort required from projects. It is useful for the cost allocation and it has the complementary value of supporting the negotiation "function vs. project managers" in a matrix organization.

Finally, although the case study has permitted an in-depth development of the methodology, multiple case studies across industries can also contribute to the robustness and generalizability of the approach.

Further development should concern the inclusion of the possibility of varying the workforce in the model in order to introduce one more degree of flexibility and to evaluate different scenarios. How rating is affected from drivers should also be analysed from the point of view of sensitivity analysis.

6. REFERENCES

[1] Banker, R.D., Potter, G. and Schroeder, R.G. (1995), *"An empirical analysis of manufacturing overhead cost drivers"*, Journal of Accounting and Economics, Vol. 19, No. 1, pp. 115-137.

[2] Ben-Arieh, D. and Qian, L. (2003), *"Activity-based cost management for design and development stage"*, International Journal of Production Economics, Vol. 83, No. 2, pp. 169-183.

[3] Cooper, R. and Kaplan, R.S. (1987), *"How cost accounting systematically distorts product costs"*, Accounting and management: Field study perspectives, pp. 204-228.

[4] Johnson, H.T. and Kaplan, R.S. (1987), *"The rise and fall of management accounting [2]"*, Strategic Finance, Vol. 68, No. 7, p. 22.

[5] Rogerson, W.P. (1992), *"Overhead allocation and incentives for cost minimization in defense procurement"*, Accounting Review, pp. 671-690.

[6] Cooper, R. and Kaplan, R.S. (1988), *"Measure costs right: make the right decisions"*, Harvard business review, Vol. 66, No. 5, pp. 96-103.

[7] Cooper, R. and Kaplan, R.S. (1992), *"Activity-based systems: Measuring the costs of resource usage"*, Accounting Horizons, Vol. 6, No. 3, p. 1.

[8] Beheshti, H.M. (2004), *"Gaining and sustaining competitive advantage with activity based cost management system"*, Industrial Management & Data Systems, Vol. 104, No. 5, pp. 377-383.

[9] Cooper, R. and Kaplan, R.S. (1991), *"Profit priorities from activity-based costing"*, Harvard business review, Vol. 69, No.3, pp. 130-135.

[10] Kennedy, T. and Affleck-Graves, J. (2001), *"The impact of activity-based costing techniques on firm performance"*, Journal of management accounting research, Vol. 13, No. 1, pp. 19-45.

[11] Kaplan, R.S., and Anderson, S.R. (2003), Time-driven activity-based costing. Available at SSRN: http://dx.doi.org/10.2139/ssrn.485443.

[12] Zika-Viktorsson, A., Sundström, P. and Engwall, M. (2006). *"Project overload: An exploratory study of work and management in multi-project settings"*, International Journal of Project Management, Vol. 24, No. 5, pp. 385-394.

[13] Patanakul, P. and Milosevic, D. (2008), *"A competency model for effectiveness in managing multiple projects"*, The Journal of High Technology Management Research, Vol. 18, No. 2, pp. 118-131.

[14] Zeng, J., An, M. and Smith, N.J. (2007), *"Application of a fuzzy based decision making methodology to construction project risk assessment"*, International journal of project management, Vol. 25, No. 6, pp. 589-600.

[15] Saadat, M., Tan, M.C., Owliya, M. and Jules, G. (2013), *"Challenges and trends in the allocation of the workforce in manufacturing shop floors"*, International Journal of Production Research, Vol. 51, No. 4, pp. 1024-1036.

[16] Holder, A. (2005), *"Navy personnel planning and the optimal partition"*, Operations research, Vol. 53, No. 1, pp. 77-89.

[17] Aykin, T. (2000), *"A comparative evaluation of modeling approaches to the labor shift scheduling problem"*, European Journal of Operational Research, Vol. 125, No. 2, pp. 381-397.

[18] Ernst, A.T., Jiang, H., Krishnamoorthy, M. and Sier, D. (2004), *"Staff scheduling and rostering: A review of applications methods and models"*, European journal of operational research, Vol. 153, No. 1, pp. 3-27.

[19] Chien, C.F., Chen, W.C. and Hsu, S.C. (2010), *"Requirement estimation for indirect workforce allocation in semiconductor manufacturing"*, International Journal of Production Research, Vol. 48, No. 23, pp. 6959-6976.

[20] Scott, S. and Simpson, R. (1998), *"Case-bases incorporating scheduling constraint dimensions-experiences in nurse rostering"*, European Workshop on Advances in Case-Based Reasoning, pp. 392-401, Springer Berlin Heidelberg.

[21] Li, J.F. and Tan, Y.J. (2004), *"The guided local search method for a class of work-force scheduling problems"*, Systems Engineering, Vol. 22, No. 9, pp. 87-91.

[22] Virginas, B., Voudouris, C., Owusu, G. and Anim-Ansah, G. (2007), *"ARMS Collaborator—intelligent agents using markets to organise resourcing in modern enterprises"*, BT Technology Journal, Vol. 25, No. 3-4, pp. 254-259.

[23] Tsang, E.P., Gosling, T., Virginas, B., Voudouris, C., Owusu, G. and Liu, W. (2008), *"Retractable contract network for empowerment in workforce scheduling"*, Multiagent and Grid Systems, Vol. 4, No. 1, pp. 25-44.

[24] Wirojanagud, P., Gel, E.S., Fowler, J.W. and Cardy, R. (2007), *"Modelling inherent worker differences for workforce planning"*, International journal of production research, Vol. 45, No. 3, pp. 525-553.

[25] Fowler, J.W., Wirojanagud, P. and Gel, E.S. (2008), *"Heuristics for workforce planning with worker differences"*, European Journal of Operational Research, Vol. 190, No. 3, pp. 724-740.

[26] Gans, N. and Zhou, Y.P. (2002), *"Managing learning and turnover in employee staffing"*, Operations Research, Vol. 50, No. 6, pp. 991-1006.

[27] Kaufman, D.L., Ahn, H.S. and Lewis, M.E. (2005), *"On the introduction of an agile, temporary workforce into a tandem queueing system"*, Queueing Systems, Vol. 51, No. 1-2, pp. 135-171.

[28] Sarno, D. and Nenni, M.E. (2016), *"Daily nurse requirements planning based on simulation of patient flows"*, Flexible Services and Manufacturing Journal, pp. 1-24.

[29] Cheang, B., Li, H., Lim, A. and Rodrigues, B. (2003), *"Nurse rostering problems––a bibliographic survey"*, European Journal of Operational Research, Vol. 151, No. 3, pp. 447-460.

[30] Alfares, H.K. and Bailey, J.E. (1997), *"Integrated project task and manpower scheduling*", IIE transactions, Vol. 29, No. 9, pp. 711-717.

[31] Faaland, B. and Schmitt, T. (1993), *"Cost-based scheduling of workers and equipment in a fabrication and assembly shop"*, Operations Research, Vol. 41, No. 2, pp. 253-268.

[32] Gans, N., Shen, H., Zhou, Y.P., Korolev, N., McCord, A. and Ristock, H. (2015), *"Parametric forecasting and stochastic programming models for call-center workforce scheduling"*, Manufacturing & Service Operations Management, Vol. 17, No. 4, pp. 571-588.

[33] Wallace, R.B. and Whitt, W. (2005), *"A staffing algorithm for call centers with skill-based routing"*, Manufacturing & Service Operations Management, Vol. 7, No. 4, pp. 276-294.

[34] Daduna, J.R., Branco, I. and Paixao, J.M. eds. (1995), *"Computer-aided transit scheduling"*, Proceedings of the Sixth International Workshop on Computer-aided Scheduling of Public Transport (Vol. 430). Springer Science & Business Media.

[35] Gomar, J.E., Haas, C.T. and Morton, D.P. (2002), *"Assignment and allocation optimization of partially multiskilled workforce"*, Journal of construction Engineering and Management, Vol. 128, No. 2, pp. 103-109.

[36] Hendriks, M.H.A., Voeten, B. and Kroep, L. (1999), *"Human resource allocation in a multi-project R&D environment: resource capacity allocation and project portfolio planning in practice"*, International Journal of Project Management, Vol. 17, No. 3, pp. 181-188.

[37] Huemann, M., Keegan, A. and Turner, J.R. (2007), *"Human resource management in the project-oriented company: A review"*, International Journal of Project Management, Vol. 25, No. 3, pp. 315-323.

[38] Tong, T.K. and Tam, C.M. (2003), *"Fuzzy optimisation of labour allocation by genetic algorithms"*, Engineering, Construction and Architectural Management, Vol. 10, No. 2, pp. 146-155.

[39] Saaty, T.L. (1990), *"How to make a decision: the analytic hierarchy process",* European journal of operational research, Vol. 48, No. 1, pp. 9-26.

[40] Chang, C.W., Wu, C.R., Lin, C.T. and Chen, H.C. (2007), *"An application of AHP and sensitivity analysis for selecting the best slicing machine"*, Computers & Industrial Engineering, Vol. 52, No. 2, pp. 296-307.

[41] Huang, C.C., Chu, P.Y. and Chiang, Y.H. (2008), *"A fuzzy AHP application in government-sponsored R&D project selection"*, Omega, Vol. 36, No. 6, pp. 1038-1052.

[42] Cannavacciuolo, L., Iandoli, L., Ponsiglione, C. and Zollo, G. (2012), *"An analytical framework based on AHP and activity-based costing to assess the value of competencies in production processes"*, International Journal of Production Research, Vol. 50, No. 17, pp. 4877-4888.

[43] Samvedi, A., Jain, V. and Chan, F.T. (2012), *"An integrated approach for machine tool selection using fuzzy analytical hierarchy process and grey relational analysis"*, International Journal of Production Research, Vol. 50, No. 12, pp. 3211-3221.

[44] Perić, T., Babić, Z. and Veža, I. (2013), *"Vendor selection and supply quantities determination in a bakery by AHP and fuzzy multi-criteria programming"*, International Journal of Computer Integrated Manufacturing, Vol. 26, No. 9, pp. 816-829.

[45] Saaty, T.L. (2004), *"Decision making—the analytic hierarchy and network processes (AHP/ANP)"*, Journal of systems science and systems engineering, Vol. 13, No. 1, pp. 1-35.

[46] Saaty, T.L. (1982), *"The analytic hierarchy process: A new approach to deal with fuzziness in architecture"*, Architectural Science Review, Vol. 25, No. 3, pp. 64-69.

[47] Goepel, K.D. (2013), *"June. Implementing the analytic hierarchy process as a standard method for multi-criteria decision making in corporate enterprises–a new AHP excel template with multiple inputs"*, In Proceedings of the international symposium on the analytic hierarchy process, pp. 1-10.

[48] Spearman, C. (1906), *"'Footrul' for measuring correlation"*, British Journal of Psychology, 1904-1920, Vol. 2, No. 1, pp. 89-108.

[49] Bar-Ilan, J., Levene, M. and Lin, A. (2007), *"Some measures for comparing citation databases"*, Journal of Informetrics, Vol. 1, No. 1, pp. 26-34.

Pristup zasnovan na procesu analitičke hijerarhije za raspodelu indirektnih troškova rada

Cristina Ponsiglione, Maria Elena Nenni, Gianfranco Castellano, Armando Molisso

Primljen (04.09.2017.); Recenziran (20.12.2017.); Prihvaćen (17.01.2018.)

Apstrakt

Ova studija ima za cilj da predloži metodološki pristup koji podržava raspodelu indirektnih troškova rada na različite projekte u kompleksnim multi-projektnim okruženjima. Svrha je izgradnja fleksibilne metodologije zasnovane na principima koštanja zasnovanim na aktivnostima, koja je pogodna u svim situacijama koje karakterišu visoki uticaji indirektnih troškova rada i određeni nivoi poslovne složenosti. Predložena metodologija se zasniva na primeni pristupa analitičke hijerarhije procesa (AHP) za kreiranje rangiranja projekata zasnovanih na višestrukim kriterijumima. Indirektni troškovi rada se zatim raspoređuju srazmerno dobijenim relativnim težinama. Metodologija je testirana u multi-projektnoj organizaciji koja radi u odbrambenoj industriji. Rezultati studije slučaja pokazuju da predloženi pristup zasnovan na AHP-u može pružiti metodu koja uzima u obzir subjektivnost i jedinstvenost aktivnosti koje obavljaju ljudi. Istovremeno, razvijeni višekriterijumski pristup je dovoljno fleksibilan da se prilagodi zahtevima različitih upravljačkih struktura i promenama u portfoliju projekata.

Primena ovog pristupa sada je ograničena na samo jednu studiju slučaja, ali čak i ako je u budućnosti poželjna strategija istraživanja višestrukih studija slučaja, to ne utiče na robustnost i generalizaciju metodologije.

Ključne reči: *Višekriterijumska analiza; Planiranje ljudskih resursa; Troškovi zasnovani na aktivnostima; Analitički hijerarhijski proces; Okruženje za više projekata.*