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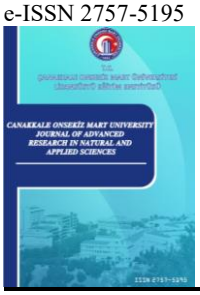

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A Maturity Model for Assessing Sustainable Project Management Knowledge Areas: A Case Study Within A Logistics Firm

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Research Article

Abstract − Currently, the use of maturity models is widespread for evaluating the success of project management (PM) processes. Project management maturity models (PMMM) are valuable methodologies to improve the project management processes. In this context, this present paper seeks an answer to these questions: Which maturity levels are aimed for an organization to make the sustainable PM sound? Which propositions are made based on the obtained maturity levels? This paper aims to propose a PMMM by analysing PM knowledge areas. In response to this objective, nine dimensions and twenty seven maturity items are handled using of PM Solutions' PMMM. In order to evaluate the maturity levels, Weighted Maturity Score Calculation Model (WMSC) approach based on survey questionnaires of two experts is used first for the PM knowledge areas. Weighted average score of all maturity items is obtained using Likert-scale and criteria weights are first calculated using Hesitant Fuzzy Analytical Hierarchy Process (HF-AHP). Practicality of these approaches is illustrated through a real data in a logistics organization**.** As a result, computational results indicate that risk management dimension with the level 1,4 has the lowest rating of all nine dimensions. The high maturity level 3,5 is observed in the quality management, as the maturity items in this dimension such as Quality Plan Preparation and Quality Plan Employment can have a favourable impact on the PM maturity. The findings reveal the effectiveness of the proposed method, which ensures practical and theoretical insights for organizations to determine their current and expected sustainable project maturity levels.

Keywords − *HF-AHP, maturity level, pm maturity model, project management, sustainability*

1. Introduction

PM requires the incorporating information, skill and methods into project processes (Ofori & Deffor, 2013). To improve PM's efficiency, sustainability and PM should be integrated (Marcelino-Sádaba, González-Jaen & Pérez-Ezcurdia, 2015). Sustainable PM requires management of the projects being aware of the environment and society impacts. In recent years, due to the transformation of classical PM systems, modern performance measurement methods are handled in several sectors. Organizations use some conceptual tools called project management maturity models (PMMM) to improve their project management processes (Farrokh & Mansur, 2013). Maturity term is used to define a company's ability in performing it's task and it is now more widely used for logical mapping, especially in the software industry (Crawford, 2007). PM maturity is also defined as the development of methodologies, strategies and decision-making processes of the organizations. Although there is no main PMMM maturity model, researchers suggest two models, process-oriented and work-oriented (Khalema, Van Waveren, & Chan, 2015). In this paper, sustainability-oriented model is presented to guide the firm toward sustainability. A PM is defined as sustainable involving company culture, human resource skills, using of resources, etc. (Tharp, 2012).

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Various PY maturity models are used based on some criteria (Nenni, Arnone, Boccardelli & Napolitano, 2014). Organizational Project Management Maturity Model (OPM3) developed by Project Management Institute (PMI) offers a system that combines the project, program and portfolio management of institutions: Information, Organizational strategy, People, Processes. OPM3 provides flexibility in terms of size of institutions, complexity of projects and geography (PMI-OPM3, 2013). The Capability Maturity Model (CMM) of Software Engineering Institute (SEI) is used by institutions dealing with software business. Kerzner Project Management Maturity Model (K-PMMM) was developed in 2002. K-PMMM enables institutions to reach maturity by using PMBOK guidelines (Kerzner, 2002). The Project, Program and Portfolio Management Maturity Model (P3M3) is divided into three sub model (OGC, 2011): Portfolio Management, Program Management, Project Management. The Maturity Increases Model in Controlled Environments (MINCE) measures the adaptation of institutions to environmental and market changes and the maturity of the organization, the skill levels of the personnel, the effectiveness of their projects, the ability to adapt to change the organizational past lessons (Meisner, 2007). PM Solutions PMMM analyse the PM knowledge areas and maturity levels depicted in Figure 1.

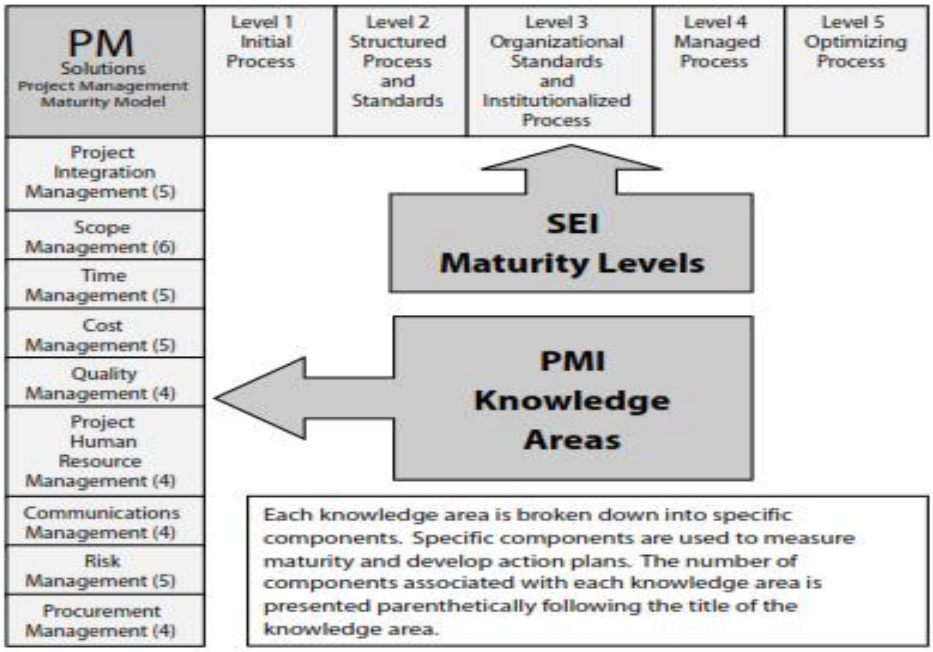

Figure 1. PMMM of PM solutions (PMI)

PMI knowledge areas are divided into nine groups:

Project integration management can be defined as the coordination of the all project management processes. In addition, it is defined as the process starting with a project charter and ending with the project completion (Wysocki, 2014). Scope management is defined as the process to identify all activities, processes and to eliminate irrelevant areas (Heldman, 2018). Scope management includes a lot of activities such as requirement definitions, creating work breakdown structure (WBS). Time management controls the time on the activities by a variety of skills and tools using CPM (Critical Path Method) and PERT (Programme Evaluation and Review Technique). These methods are used to evaluate the time of the specific projects. Cost management ensures to complete the project between defined budget limits. Quality management involves the sub stages such as quality planning, assurance and control stages. This management aims the quality requirements defined for the projects. The aim of the human resource management ensures that people participate in the project at the highest rate. For this, first of all, necessary trainings are given to general managers, owner / sponsor, project managers and project team. Project human resources management is an integration of organizational planning, staffing, team development processes. The aim of this process is to ensure that

the people of the project team work at the highest rate. Communications management ensures that the information used in the project is optimal and important connections between the collected information and people. Risk management identifies potential hazards and provides risk strategies. Risk definition, risk measures, risk reactions and control stages are implemented and resources are provided for possible risk events. Procurement management is the process of conducting resources, purchasing of goods and services procurement planning, bid planning, contract management, contract completion activities. SEI maturity levels depicted in the figure are not used to evaluate the knowledge areas in the present paper. The survey questionnaires are employed to analyse the maturity levels based on the Likert scale.

PMMMs have attracted attention by researchers and practitioners. However, PM knowledge areas, especially sustainable metrics in this context, are not sufficiently studied. Hatamleh, Moynihan, Alzarrad & Batson (2020) use PMMM using measurement tools to evaluate the capabilities in project management applications. Measurements are obtained through interviews by experts. The results show that there is no difference between the contractor and the consultant in terms of maturity levels. Sanchez, Steria, Bonjour, Micaelli & Monticolo (2020) proposes a framework for predicting the effects of the PMM model on the performance of the project using Bayesian networks. The study aims to minimize the cost risks for large projects. Cooke-Davies and Arzymanow (2003) measure the differences between applications based on measuring project management maturity in different sectors. Interviews are held with project managers using qualitative methods. The most advanced maturity model is obtained in the Petrochemical and Defence sector. Görög (2016) offers a broad project management maturity assessment approach. The interactions of the three maturity levels (single project, project program, organizational project governance structure) are investigated and the development strategy is formulated. Caiado et al. (2021) present preliminary works, surveys, case studies, and a maturity model using fuzzy approach and simulation, including design of maturity models. The proposed model validated through a case study results the necessary actions to increase the maturity level. Backlund, Chronéer, & Sundqvist (2014) explores project management maturity and models to develop and improve the project management practices of engineering and construction companies. Interviews are conducted with the project managers about the rate of use of maturity models. In the study, the application of the model in a mining company is shown with a case study. Based on literature reviews on existing maturity models, Tahri and Drissi-Kaitouni (2015) provide a maturity model to calculate PMM, in which sequential and progressive models are followed. de Souza and Gomes (2015) conduct a bibliometric analysis of PMM assessment models. Data analysis is performed using descriptive statistics. Lianying, Jing, & Xinxing (2012), through the literature review, PRINCE2 (Projects in Controlled Environments) process method is developed. This model uses a rating system, a survey, a spider web model. Pasian, Sankaran & Boydell (2012) examines project management maturity and the limitations of related models. A two-step multi-method is supported by a content / text analysis of two different maturity model collections. Obtained results suggest that assessing the maturity of project management capabilities include adaptive variables such as client engagement, organizational dynamics, and leadership. Brookes, Butler, Dey & Clark (2014) conducts an experimental study to investigate the effects of PMMMs on improving project performance using cross case analysis. A high degree of variability in the individuals' assessments of PMM is observed in the study. Nenni, Arnone, Boccardelli & Napolitano (2014) investigate the scope improvement in order to develop the PMMMS as business-oriented frameworks. OPM3 is obtained as the most complete and effective maturity model. Lores, Nguyen, Lydia, & Shankar, 2019 explore the different levels and models of PMM. The holistic and progressive approach that implements the project management maturity and strategy, organizational approach, methodology and decision-making process, is defined on the basis of processes, tools and people, which are the 3 main areas of project management. Fengyong and Renhui (2007) develop a new construction PMMM to evaluate the construction projects. In addition, new evaluation techniques are investigated for the construction PMM. Guangshe et al. (2008) evaluate the limitations and assessment of the PMM of OPM3. Jamaluddin, Chin & Lee (2010) aims to evaluate the current state of adoption of the PMMM as a model conceptualization initiative. An online survey is conducted to investigate the level of awareness and applications of the model. Irfan et al. (2020) present a maturity model using Partial Least Squares Structural Equation Modeling (PLS-SEM).

In the study, maturity levels and reputation are observed as linked terms. Also, some dimensions of PMMM positively important on this reputation. Wijaksono, Pratami & Bay (2020) use the OPM3 to assess the maturity levels. The risk management knowledge area is the focus of the study. The research is conducted using a questionnaire. The results show that the maturity level of the company is at the lowest level. Bolat, Kuşdemir, Uslu, & Temur (2017) aim to provide a framework for measuring the maturity level and they show how variable the PMM based on company characteristics conducting a case study involving 16 companies. The results reveal the relationship between problems arising in project management processes, company structure and PM skills. de Souza Scotelano, da Conceição, da Costa Leonídio, & de Jesus (2017) discuss the theoretical concepts related to project management, especially the concepts of measurement of its implementation. In addition, results of survey data conducted in an automotive industry through maturity research are presented. This survey reveals the perceptions of employees in different fields regarding project maturity in this organization. In addition, it reveals that the analysed organization is at the observed and calculated levels, taking into account the average maturity level of the region and the country. Gasik (2019), State Project Implementation System (GPIS) and State Project Management (GPM) concepts and State Project Management Maturity Model (GPM3) are defined. A GPM3 includes a GPIS / GPM maturity model consisting of Beginner, Local, Management, Collaboration and Optimization levels. The study reveals the advantages of introducing GPIS and GPM and using GPM3. Spalek (2015) provides a conceptual model for evaluating PMM with literature review and interviews in his study. The model is based on four assessment areas such as human resources, methods and tools, and environment, knowledge management. The proposed model can be used to evaluate maturity levels in companies on a global scale and to conduct cross-comparative research.

In short, some researchers consider the various maturity models to calculate the maturity levels of the organizations. However, few articles consider the influence of maturity models on project management knowledge areas. In order to overcome this gap, a maturity calculation model is proposed in conjunction with the work Schumacher, Erol, & Sihn 2016) firstly for a PM system. Furthermore, this paper is first to integrate the Likert scale for average score of the maturity items and HF-AHP for criteria weights to employ the maturity calculation model. HF-AHP is preferred since two experts have hesitancy in linguistic assessments. Considering sustainable metrics to evaluate the maturity levels of the maturity items is also a contribution to achieve the sustainability objectives. Thus, considering the above factors, some following research questions are listed as follows.

- RQ1: Which maturity levels are aimed for an organization to make the sustainable PM sound
- RQ2: Which propositions are made based on the obtained maturity levels?

Thus, to respond to questions RQ1 and RQ2, detecting possible maturity levels based on the maturity items and sustainability metrics is conducted using the proposed methods. Then, measures to increase the maturity levels are proposed according to the obtained computational results. This paper utilizes a decision support system, HF-AHP, in order to decide the dimension and item weights. Main contributions of this research are provided in the following:

- WMSC model as a solution approach is presented first for the PM knowledge areas.
- PM knowledge areas are evaluated incorporating sustainability aspects.
- Impact of the Likert scale instead of the SEI levels on average scores of the maturity items is investigated.
- HF-AHP is first used to calculate the dimension and item weights of PMMM.
- The maturity model has been implemented on real case data to guide the firms for their decision making processes about the maturity levels.

2. Materials and Methods

As mentioned in the above sections, developing a maturity model is vital to measure and evaluate the PM capability and to improve the PM levels. PM Solutions' PMMM ensures this measurement to organizations for calculating their ability. The proposed maturity model has the following characteristics: A survey based on a short questionnaire, five levels from 1- "not implemented" to 5- "fully implemented, nine dimensions named PM knowledge areas and twenty-seven items containing sustainability metrics. This survey was applied with 27 questionnaires in the project office. These questionnaires were prepared based on the 27 maturity items. Two experts rated these questionnaires in a five point Likert scale.

In this paper, providing a decision support system (DSS) is aimed to cover the dimensions of a PM knowledge area. This system can support project managers in their decisions how to conduct the PM processes. In this context, DSS could be classified in two stages: determining the maturity model components and maturity levels of PM knowledge area dimensions and items. Within first stage, a survey is formed for each dimension and a HF-AHP approach is used for criteria weights. In the second stage, all components obtained by the first stage are connected to the calculation of the maturity level, where all levels of both dimensions and the maturity items are determined.

2.1. Research Steps

The proposed methodology steps are presented in Figure 2. Definitions of these steps are presented as below:

(i) The articles are gone through in-depth. This stage embraced the analysing of existing PMMMs and gaps in the area.

(ii) Survey questionnaires aim to decide the scores of a set of dimensions and maturity items. A survey is the set of questions replied by respondents related with the current project. The questionnaires intend to measure PM knowledge area dimensions and its maturity items. Then, the dependent variable, average score of all maturity items is measured. A five point Likert-Scale is conducted based on the experts' evaluations.

(iii) HF-AHP implementation consisting of the decision makers' hesitant decisions.

(iv) A case study for a logistics firm and proposal of action plans for maturity improvement.

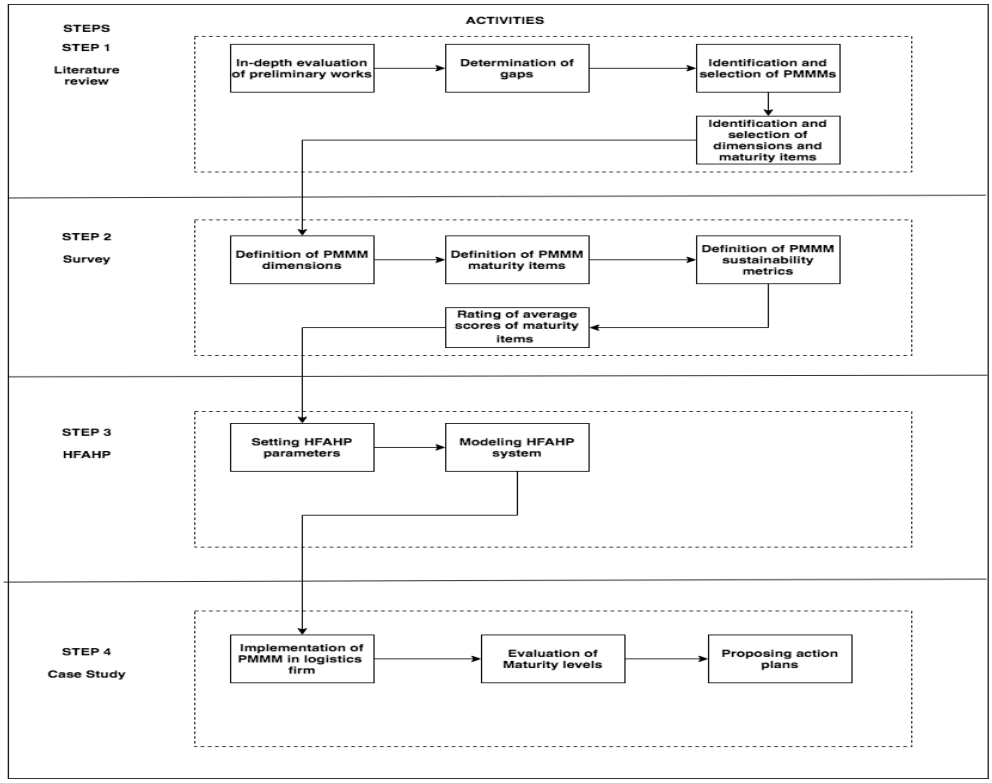

Figure 2. The proposed methodology steps

Measuring and evaluation of the organization's maturity is defined in three-stages: Measurement of dimensions and maturity items, calculation of weighting factor and creating a maturity report using radar chart. Dimensions and maturity items are presented in the Table 1. Each dimension are evaluated mainly with sub maturity items. In this firm, these items are considered based on the sustainability.

Table 1
Dimensions and maturity items for the project management maturity

Dimensions	Maturity items	Sustainability metrics
Integration Management	Project Charter	Organization environmental metrics
	PM Plan	Process assets
	Project Control	Performance reports
Scope Management	Scope Definition	Integration of the social and environmental aspects into the scope
	Work Breakdown Structure	
	Scope Control	Meeting the sustainability standards
		Performance reports
Time Management	Activity Definition	Short term, long term oriented activity definition
	Activity Resource Determination	
	Schedule Control	Schedule forecasts
		Performance reports
Cost Management	Financial and Sustainability Targets	Accountability and transparency
	Budget Determination	Balancing the economic and ecological budget distribution
	Cost Control	
		Performance reports
Quality Management	Quality Plan Preparation	Incorporating social aspects
	Quality Plan Employment	Quality control measurements
	Quality Control	Quality improvement methods
Human Resources Management	Human Resources Plan Preparation	Human values and ethics
	Team Training	Responsibility assignment
	Team Management	Respect for human rights
Communication Management	Stakeholder Communication	Proactive Stakeholder Participation
	Communication Plan Preparation	Interpersonal and team skills
	Information Sharing	Timely and relevant information
Risk Management	Risk Definition	Short term, long term oriented risk definition
	Risk Analysis Methods	
	Risk Measurements Planning	Reducing risk factors
		Improving risk measurements
Procurement Management	Procurement Plan Preparation	Knowledge transfer
	Supplier Determination	Adding value for the suppliers
	Procurement Contract Management	Accountability and transparency

Determination of the maturity levels is conducted with the WMSC model developed by (Schumacher et al., 2016). The maturity levels ($\mathbf{M_D}$) of the dimensions are obtained with scoring maturity items ($\mathbf{M_{DIi}}$) and the weighting- factor ($\mathbf{g_{DIi}}$). (M Maturity level, D Dimension, I item, g weighting factor, n number of maturity item). The Equation (2.1) is presented in the following:

$$M_D = \frac{\sum_{i=1}^{n} M_{DIi} * g_{DIi}}{\sum_{i=1}^{n} g_{DIi}} \quad (2.1)$$

The maturity items are measured based on the survey questionnaires. Each question is answered based on a Likert-scale (1- "not implemented", "2 – slightly implemented, 3 – moderately implemented, 4 – mostly implemented", "5- "fully implemented"). An example for the survey based on the scale is presented in the Table 2. For project time management, activity definition and resource determination are moderately implemented while schedule control is slightly implemented.

Table 2
An example for the survey to measure the dimensions and maturity items

Dimensions and maturity items	1	2	3	4	5
Project Time Management			X		
Activity Definition			X		
Activity Resource Determination			X		
Schedule Control		X			

In order to determine the weighting factor (g_{DIi}), HF-AHP is employed. HF-AHP method, which is used to decide the criteria weights, is an integrated approach including Hesitant Fuzzy Sets (HFS) and Hesitant Fuzzy Linguistic Expression Sets (HF-LS) and F-AHP. The steps of this method are presented in the following:

Step 1: Defining the set of linguistic terms D= [D0, D1,…, Dn)

Step 2: Binary comparisons of dimensions with HF-LS.

Step 3: Generation of data envelops env[dij] including expressions of i, j dimensions.

Step 4: Tabulation of expressions with the corresponding triangular fuzzy number (TFN).

Step 5: Conversion of data envelopes env[dij] to data envelopes involving TFNs.

Step 6: Calculation of mean of TFNs in the data envelopes.

Step 7: Geometric mean for each criterion I (Eq. 2.2)

$r_i = (\sum_{j=1}^{n} d_{ij})^{1/n}$ i= 1,2,…,n (2.2)

Step 8: Calculation of fuzzy weights for each criterion I (Eq. 2.3)

$w_i = r_i \otimes (r_1 \otimes r_2 \otimes .. \otimes r_n)^{-1} = (lw_i, mw_i, uw_i)$ (2.3)

lw_i: *lower weight of criteria* i, mw_i: *medium weight of criteria* i, uw_i: *upper weight of criteria* i

Step 9: Clarification of the FNs with the area center method (Eq. 2.4) (Chou and Chang, 2008).

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (2.4)$$

Step 10: Normalization of the clarified numbers and calculation of each criterion weight (Eq. 2.5).

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (2.5)$$

3. Results and Discussion

Here, the results of the HF-AHP for the case study are obtained. The respondents presented similar ratings. For a respondent, pairwise comparisons of dimensions are demonstrated in Table 3.

Step 1: Linguistic expression sets are defined.

S = {Equally Important [EQ], Weakly Important [WI], Strongly Important [SI], Very Strongly Important [VSI], Absolutely Important [AI]}.

Step 2: In this stage, the pairwise comparisons belonging to two experts are presented in Table 3. Decision makers have hesitancy in providing their preferences over dimensions. For example, Expert 1 decides the integration management is more strongly important than scope management while the other expert provides his preference as weakly important.

Table 3
An example of pairwise comparisons

AI	VSI	SI	WI	Dimension	EQ	Dimension	WI	SI	VSI	AI
		✓	✓	Integration Management		Scope Management				
		✓		Scope Management		Time Management				
		✓	✓	Time Management		Cost Management				
				Cost Management		Quality Management			✓	
	✓			Quality Management		Human Resources Management				
				Human Resources Management		Communication Management		✓	✓	
		✓	✓	Communication Management		Risk Management				
			✓	Risk Management		Procurement Management				
				Procurement Management		Cost Management	✓			

Step 3: Generation of data envelopes including expressions for the dimensions is presented in Table 4. For example, Expert 1 decides the integration management is more strongly important [SI] than scope management while the other expert provides his preference as weakly important [WI].

Table 4
The envelope of linguistic terms for each i-j pair of criteria

Dimension	**Integration Management**	**Scope Management**	**Time Management**	**Cost Management**	**Quality Management**	**Human Resources Management**	**Communication Management**	**Risk Management**	**Procurement Management**
Integration Management	[EQ]	[WI, SI]	[VSI]	[VSI]	[VSI]	[VSI]	[VSI]	[VSI]	[VSI]
Scope Management	-	[EQ]	[SI]	[SI]	[WI]	[VSI]	[SI]	[VSI]	[VSI]
Time Management	-	-	[EQ]	[WI,SI]	-	[WI, SI]	[WI, SI]	[WI]	[WI,SI]
Cost Management	-	-	-	[EQ]	-	[WI]	[WI]	[WI]	[WI]
Quality Management	-	-	[SI]	[VSI]	[EQ]	[VSI]	[WI]	[VSI,SI]	[VSI]
Human Resources Management	-	-	-	-	-	[EQ]	-	-	-
Communication Management	-	-	-	-	-	[SI,VSI]	[EQ]	[WI,SI]	[WI]
Risk Management	-	-	-	-	-	[WI]	-	[EQ]	[WI]
Procurement Management	-	-	-	-	-	[WI]	-	-	[EQ]

Step 4: Determination of linguistic expressions and the corresponding TFNs is presented in Table 5.

Table 5
Expressions with corresponding TFNs

Linguistic terms	**TFN**	**Inverse TFN**
Equally Important [EQ],	(1, 1, 1)	(1, 1, 1)
Weakly Important [WI]	(2, 3, 4)	(1/4, 1/3, 1/2)
Strongly Important [SI]	(4, 5, 6)	(1/6, 1/5, 1/4)
Very Strongly Important [VSI]	(6, 7, 8)	(1/8, 1/7, 1/6)
Absolutely Important [AI]}	(9, 9, 9)	(1/9, 1/9, 1/9)

Step 5: Converting data envelopes to data envelopes involving triangular fuzzy numbers is presented in Table 6. For example; comparing the dimensions " Project integration management and scope management"(Eq. 3.1)

env[dI-S] = [(2.000,3.000, 4.000)]; [(4.000,5.000, 6.000)] (3.1)

env[dS-I] = [(1/6.000), (1/5.000),(1/4.000)]; [(1/4.000),(1/3.000), (1/2.000)]

env[dS-I] = [(0.166,0.200, 0.250)] ; [(0.250,0.333, 0.50)]

Table 6
The envelope of TFNs for each pair of criteria

Dimension	**Integration Management**	**Scope Management**	**Time Management**	**Cost Management**	**Quality Management**	**Human Resources Management**	**Communication Management**	**Risk Management**	**Procurement Management**
Integration Management	[(1.000,1.000, 1.000)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]
Scope Management	[(0.250,0.333, 0.50)] [(0.166,0.200, 0.250)]	[(1.000,1.000, 1.000)]	[(4.000,5.000, 6.000)]	[(4.000,5.000, 6.000)]	[(2.000,3.000, 4.000)]	[(6.000,7.000, 8.000)]	[(4.000,5.000, 6.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]
Time Management	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(1.000,1.000, 1.000)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]	[(0.166,0.200, 0.250)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]
Cost Management	[(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(1.000,1.000, 1.000)]	[(0.125,0.142, 0.166)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]
Quality Management	[(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)]	[(4.000,5.000, 6.000)]	[(6.000,7.000, 8.000)]	[(1.000,1.000, 1.000)]	[(6.000,7.000, 8.000)]	[(2.000,3.000, 4.000)]	[(4.000,5.000,6.000)] [(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]
Human Resources Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)]	[(0.125,0.142, 0.166)]	[(1.000,1.000, 1.000)]	[(0.166,0.200, 0.250)] [(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]
Communication Management	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]	[(4.000,5.000,6.000)] [(6.000,7.000, 8.000)]	[(1.000,1.000, 1.000)]	[(2.000,3.000, 4.000)] [(4.000,5.000, 6.000)]	[(2.000,3.000, 4.000)]
Risk Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)]	[(0.166,0.200, 0.250)] [(0.125,0.142, 0.166)]	[(2.000,3.000, 4.000)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(1.000,1.000, 1.000)]	[(2.000,3.000, 4.000)]
Procurement Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)] [(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)]	[(0.125,0.142, 0.166)]	[(2.000,3.000, 4.000)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]	[(1.000,1.000, 1.000)]

Step 6: Calculation of the mean of the TFNs in the data envelopes is shown in Table 7. For the comparing the time/communication management; (Eq. 3.2)

Time [(2.000,3.000, 4.000)]; Communication[(4.000,5.000, 6.000)] (3.2)

Arithmetic averaged result = [(2.000+4.000)/2,(3.000+5.000)/2,(4.000+6.000)/2)]

= [(3.000,4.000, 5.000)]

Table 7
Arithmetic averaged fuzzy pair wise comparisons of each i-j criteria

Dimension	**Integration Management**	**Scope Management**	**Time Management**	**Cost Management**	**Quality Management**	**Human Resources Management**	**Communication Management**	**Risk Management**	**Procurement Management**
Integration Management	[(1.000,1.000, 1.000)]	[(3.000,4.000, 5.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]
Scope Management	[(0.208,0.266, 0.375)]	[(1.000,1.000, 1.000)]	[(4.000,5.000, 6.000)]	[(4.000,5.000, 6.000)]	[(2.000,3.000, 4.000)]	[(6.000,7.000, 8.000)]	[(4.000,5.000, 6.000)]	[(6.000,7.000, 8.000)]	[(6.000,7.000, 8.000)]
Time Management	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(1.000,1.000, 1.000)]	[(3.000,4.000, 5.000)]	[(0.166,0.200, 0.250)]	[(3.000,4.000, 5.000)]	[(3.000,4.000, 5.000)]	[(2.000,3.000, 4.000)]	[(3.000,4.000, 5.000)]
Cost Management	[(0.125,0.142, 0.166)]	[(0.208,0.266, 0.375)]	[(0.208,0.266, 0.375)]	[(1.000,1.000, 1.000)]	[(0.125,0.142, 0.166)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]	[(2.000,3.000, 4.000)]
Quality Management	[(0.125,0.142, 0.166)]	[(0.250,0.333, 0.500)]	[(4.000,5.000, 6.000)]	[(6.000,7.000, 8.000)]	[(1.000,1.000, 1.000)]	[(6.000,7.000, 8.000)]	[(2.000,3.000, 4.000)]	[(5.000,6.000,7.000)]	[(6.000,7.000, 8.000)]
Human Resources Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.208,0.266, 0.375)]	[(0.250,0.333, 0.500)]	[(0.125,0.142, 0.166)]	[(1.000,1.000, 1.000)]	[(0.145,0.171, 0.208)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]
Communication Management	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(0.208,0.266, 0.375)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]	[(5.000,6.000,7.000)]	[(1.000,1.000, 1.000)]	[(3.000,4.000, 5.000)]	[(2.000,3.000, 4.000)]
Risk Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.166,0.200, 0.250)]	[(0.250,0.333, 0.500)]	[(0.145,0.171, 0.208)]	[(2.000,3.000, 4.000)]	[(0.208,0.266, 0.375)]	[(1.000,1.000, 1.000)]	[(2.000,3.000, 4.000)]
Procurement Management	[(0.125,0.142, 0.166)]	[(0.125,0.142, 0.166)]	[(0.208,0.266, 0.375)]	[(0.250,0.333, 0.500)]	[(0.125,0.142, 0.166)]	[(2.000,3.000, 4.000)]	[(0.250,0.333, 0.500)]	[(0.250,0.333, 0.500)]	[(1.000,1.000, 1.000)]

Step 7: Geometric mean for each criterion i is shown in Table 8. For example, geometric mean of dimension (integration) is calculated: (Eq. 3.3)

$$r_i = [(1.000 * 3.000 * 6.000 * 6.000 * 6.000 * 6.000 * 6.000 * 6.000 * 6.000)^{\frac{1}{9}}; (1.000 * 4.000 * 7.000 * 7.000 * 7.000 * 7.000 * 7.000 * 7.000 * 7.000)^{\frac{1}{9}}; (1.000 * 5.000 * 8.000 * 8.000 * 8.000 * 8.000 * 8.000 * 8.000 * 8.000)^{\frac{1}{9}}] \quad (3.3)$$

r_i=[4.552; 5.299; 6.026]

Table 8
Geometric means of fuzzy comparison values

Dimension		**r_i**	
Integration Management	4.552	5.299	6.026
Scope Management	2.794	3.190	3,560
Time Management	0.937	1.178	1.436
Cost Management	0.605	0.787	0.999
Quality Management	1.863	2.247	2.680
Human Resources Management	0.213	0.257	0.329
Communication Management	0.586	0.732	0.935
Risk Management	0.350	0.434	0.546
Procurement Management	0.286	0.353	0.456
Total	12.186	14.477	16.967
Reverse	0.082	0.069	0.059
Increasing order	0.059	0.069	0.082

Step 8: Calculation of fuzzy weights using Equation 1 for each criterion i is presented in Table 9. For example, fuzzy weight of the integration management (i) is calculated as follows (Eq. 3.4):

$$w_i = [(4.552 * 0.059); (5.299 * 0.069); (6.026 * 0.082)] \quad (3.4)$$

$$w_i = [0.269; 0.366; 0.494]$$

Table 9
Fuzzy weights of each criterion

Dimension	**w_j**		
Integration Management	0.269	0.366	0.494
Scope Management	0.165	0.220	0.292
Time Management	0.055	0.081	0.118
Cost Management	0.036	0.054	0.082
Quality Management	0.110	0.155	0.220
Human Resources Management	0.013	0.018	0.027
Communication Management	0.035	0.051	0.077
Risk Management	0.021	0.030	0.045
Procurement Management	0.017	0.024	0.037

Step 9: Clarification of the fuzzy numbers with the area center method is presented in Table 10. For example, clarification of the integration management (i) is calculated as follows (Eq. 3.5):

$$M_i = \frac{0.269+0.366+0.494}{3} = 0.376 \quad (3.5)$$

Step 10: Normalization of the clarified numbers and calculation of each criterion weight are presented in Table 10. For example, normalization of the integration management (i) is calculated as follows (Eq. 3.6):

$$N_i = \frac{0.376}{1.037} = 0.362 \quad (3.6)$$

Table 10
De-fuzzified (Mi) and normalized (Ni) relative weights of criteria

Dimension	**Mi**	**Ni**
Integration Management	0.376	0.362
Scope Management	0.226	0.218
Time Management	0.085	0.082
Cost Management	0.057	0.055
Quality Management	0.162	0.156
Human Resources Management	0.019	0.018
Communication Management	0.054	0.052
Risk Management	0.032	0.030
Procurement Management	0.026	0.025

All weights of all dimensions, maturity items are demonstrated in Table 11. Weights of the maturity items are also obtained as the calculation of the dimensions' weights. The demonstration of the item weights' calculation is not presented due to the same steps of the dimensions. Total weights are obtained as multiplying the dimensions' weight and item weights.

Table 11
Item and total weights

Dimensions	**Maturity items**	**Item weights**	**Total weights**
Integration Management (0.362)	Project Charter	(0.255)	(0.092)
	Project Management Plan	(0.217)	(0.079)
	Project Control	(0.205)	(0.074)
Scope Management (0.218)	Scope Definition	(0.210)	(0.046)
	Work Breakdown Structure	(0.172)	(0.037)
	Scope Control	(0.160)	(0.035)
Time Management (0.082)	Activity Definition	(0.180)	(0.015)
	Activity Resource Determination	(0.090)	(0.007)
	Schedule Control	(0.154)	(0.012)
Cost Management (0.055)	Financial and Sustainability Targets	(0.047)	(0.003)
	Budget Determination	(0.119)	(0.007)
	Cost Control	(0.034)	(0.002)
Quality Management (0.156)	Quality Plan Preparation	(0.097)	(0.015)
	Quality Plan Employment	(0.128)	(0.020)
	Quality Control	(0.235)	(0.037)
Human Resources Management (0.018)	Human Resources Plan Preparation	(0.069)	(0.001)
	Project Team Training	(0.214)	(0.004)
	Project Team Management	(0.105)	(0.002)
Communication Management (0.052)	Stakeholder Communication	(0.043)	(0.002)
	Communication Plan Preparation	(0.102)	(0.005)
	Information Sharing	(0.113)	(0.006)
Risk Management (0.030)	Risk Definition	(0.045)	(0.001)
	Risk Analysis Methods	(0.114)	(0.003)
	Risk Measurements Planning	(0.103)	(0.003)
Procurement Management (0.025)	Procurement Plan Preparation	(0.056)	(0.001)
	Supplier Determination	(0.099)	(0.002)
	Procurement Contract Management	(0.119)	(0.003)

As a result, maturity levels determined by the combination of score of maturity items and weights are calculated. Table 12 summarizes these dependent parameters of the maturity level formulation. Quality management has the highest maturity level while risk management level is the lowest.

Table 12
Maturity levels of dimensions and maturity items

Dimensions /	M_D	**Maturity items**	M_{DIi}	g_{DIi}
Integration Management	3.3	Project Charter	3	(0.255)
		Project Management Plan	3	(0.217)
		Project Control	4	(0.205)
Scope Management	2.4	Scope Definition	3	(0.210)
		Work Breakdown Structure	2	(0.172)
		Scope Control	2	(0.160)
Time Management	2.4	Activity Definition	3	(0.180)
		Activity Resource Determination	2	(0.090)
		Schedule Control	2	(0.154)
Cost Management	1.6	Financial and Sustainability Targets	1	(0.047)
		Budget Determination	2	(0.119)
		Cost Control	1	(0.034)
Quality Management	3.5	Quality Plan Preparation	4	(0.097)
		Quality Plan Employment	4	(0.128)
		Quality Control	3	(0.235)
Human Resources Management	1.8	Human Resources Plan Preparation	1	(0.069)
		Project Team Training	2	(0.214)
		Project Team Management	2	(0.105)
Communication Management	2	Stakeholder Communication	2	(0.043)
		Communication Plan Preparation	2	(0.102)
		Information Sharing	2	(0.113)
Risk Management	1.4	Risk Definition	1	(0.045)
		Risk Analysis Methods	2	(0.114)
		Risk Measurements Planning	1	(0.103)
Procurement Management	2.3	Procurement Plan Preparation	1	(0.056)
		Supplier Determination	2	(0.099)
		Procurement Contract Management	3	(0.119)

After the calculation process, a visual graph named radar chart is performed to depict the maturity levels. This ensures an analysis of different dimensions in the same environment and comparing them. Analysing the results on the chart in Figure 3, it can be observed that quality management has the higher maturity level. Cost, human resources, risk and procurement management dimensions have the lower maturity levels. Accordingly, the necessary improvements should be employed on these low levels.

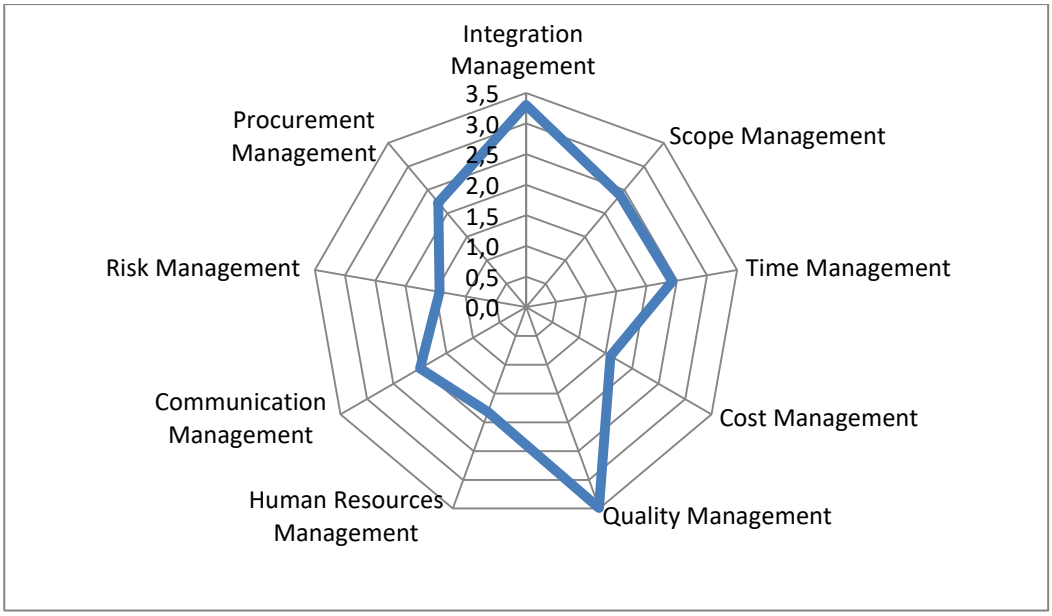

Figure 3. A radar chart for the dimensions

A radar chart is also depicted to show the maturity levels of the maturity items. The results on the chart in Figure 4 provide that project control under the dimension integration management and scope definition under the dimension scope management have the higher maturity levels. Project management plan and scope control items have the lower maturity levels. Accordingly, the measures should be taken on these low levels.

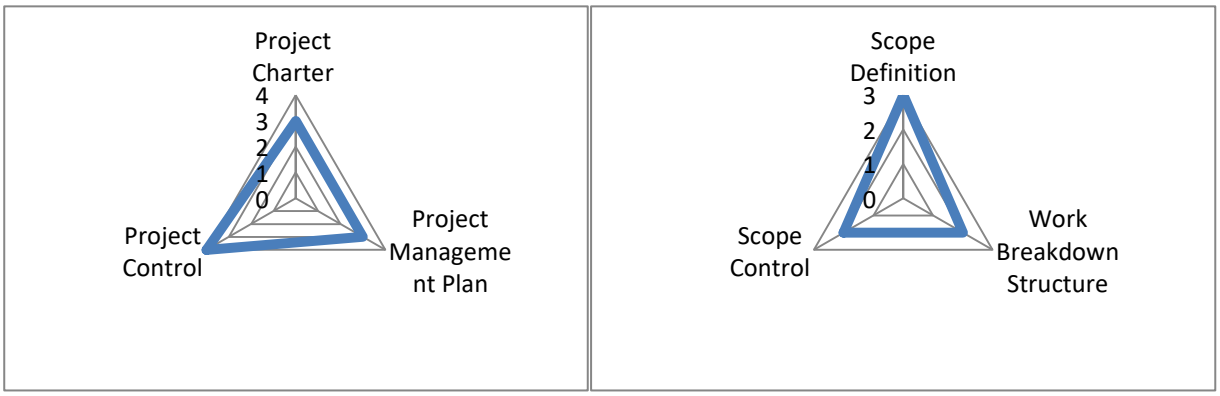

Figure 4. Radar charts for the maturity items

3.1. Sustainability Action plans

Considering the results and findings presented in previous section, recommendations are presented as an action plan in Table 13.

Table 13
Action plans for each dimension/maturity items

Action 1 Project integration management
Action 1.1. Sustainability in project integration management integrating economical, environmental and social metrics
Action 1.2. Inclusion of sustainability aims with the Project Charter
Action 1.3. Developing an economically viable, environmentally sound and socially responsible project management plan
Action 2 Scope management
Action 2.1. Incorporating of initiatives for the sustainability issues
Action 2.2. Inclusion of the organizational culture, structure, value
Action 3 Time management
Action 3.1. Actively managing the expectations of project team members to develop schedule
Action 3.2. Estimating schedule activity durations regarding conditions of work, health and safety of project team members
Action 4 Cost management
Action 4.1. Analysing of the balance between cost and benefits
Action 4.2. Higher priority to financial budget for sustainability metrics
Action 4.3. Allocation of financial resources for improving the project maturity
Action 4.4. Comprehensive cost analysis of environmental impacts
Action 5 Quality management
Action 5.1. Training on quality
Action 5.2. Incorporating sustainability considerations into company quality standards
Action 5.3. Building a firm culture that emphasizes sustainable quality management
Action 6 Human resource management
Action 6.1. Knowledge sharing to provide optimal communication for project team members
Action 6.2. A professional training program on the current project processes
Action 6.3. Improving the organizational learning
Action 6.4. Selection staff positions based on the required skills and experience
Action 6.5. Sufficient income for project team workers
Action 7 Communications management
Action 7.1. Constant feedback to customers
Action 7.2. Constant information to project managers about project status
Action 7.3. Constant communication between internal and external customers
Action 7.4. Development of internal communications through brainstorming, focus groups
Action 7.5. Wider impacts are considered such as social responsibility, global networks
Action 7.6. Improving digital communication
Action 8 Risk management
Action 8.1. Development of risk responses and monitoring risks
Action 8.2. Using a risk breakdown structure
Action 8.3. Focusing on important tasks
Action 8.4. Defining risks arising from environmental and social problems regarding previous projects
Action 9 Procurement management
Action 9.1. Development of rigorous procurement protocols
Action 9.2. Selection of suppliers including sustainability criteria
Action 9.3. Providing transparent contracts

4. Conclusion

In recent years, self-evaluation systems of the organizations have been attracted considerable attention. Maturity models are vital importance for the decision makers to measure the abilities. PMMM are important to decide whether or not the project managers take into account the improvement. PM area has great potential to outline how processes are designed based on the maturity aims. The weighted maturity score calculation can be used to evaluate the maturity levels, to improve the PM abilities. The present paper ensures a scientific view using the HF-AHP to decide the weights of maturity model and a practical view conducting implementation of the tool to a real organization. This research is first attempt to propose a PMMM, consid-

ering a series of dimensions and maturity items and sustainability metrics for a logistics firm. WMSC model is also used first for the PM knowledge areas. Impact of the Likert scale on the maturity items is investigated and HF-AHP is first used to calculate the dimension and item weights of PMMM. The proposed maturity model ensures to analyse its current and expected levels and to develop action plans. The limitation of the study is that the data is obtained by an organization therefore, they cannot be generalized. For future studies, an expert system should be developed to ensure real time, dynamic solutions for maturity gaps. Focusing on social and cultural aspects of maturity items could be evaluated by the researchers. For future works, scenario- based stochastic programming modelling and other decision making methods are recommended.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Elifcan Göçmen Polat: Designed and performed the study and wrote the paper.

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