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Reducing Inconsistency in Performance Analysis for Container Terminals

Mouhsene Fri[a,*], Kaoutar Douaioui[b], Charif Mabrouki[b] and Semma El Alami[b]

[a] *Euromed Institute of Technology (EIT). Euro-Med University of Fes, (UEMF), Route de Meknes, Fès Morocco*
[b.] *Laboratory of Engineering, of Industrial Management and Innovation Faculty of Sciences and Technology, Hassan 1st University, Settat, Morocco*

Abstract

The complexity of managing the port container terminals brings up many challenges in evaluating the global performance, so managers use the Multiple-criteria decision-making (MCDM) to assess the global performance but most of the methods are based in the experts jugements. In the case where we have a false judgment by experts, the final results will be wrong. This paper aims to develop the performance measurement system in port container terminals in order to assist decision-maker to evaluate the port container terminal. Furthermore, the paper proposes a novel framework which aims to detect and modify jugement in order to reduce inconsistancies. By reducing inconsitency, the performance results and analysis will be more stable and robust. The proposed framework combines two methods, the multiple criteria analysis using MACBETH method (Measuring Attractiveness by a Categorical Based Evaluation Technique) and DELPHI method. In order to give more legitimacy, the model is tested in four ports.

Keywords: Performance measurement system; Performance indicators; Port container terminal; DELPHI method; MACBETH method.

1. Introduction

Port container functions have evolved considerably since the Second World War, this evolution is marked by four generations. According to (UNCTAD): the first generation before 1960, the second generation between (1960 and 1980), the third generation (1980, 2000) and the fourth generation since (1999, 2011). In conformity with UNCTAD report (UNCTAD 1999), the concept of fourth generation port, is interested mainly in the following eight categories: quality of service, information technology, impact on the community environment, port cluster, maritime cluster, logistics hub, domestic, water side.

Currently some authors declare the beginning of the fifth generation port, Flynn et al. defines the fifth generation as customer-centric and community focused ports, with service deliverables related to port users multifaceted business requirements, while also taking care of community stakeholder requirements (Flynn and Notteboom 2011) . The evolution was based on the multiplication of goods transported via port terminals, which is the weakest link in the logistics chain. Generally, Port terminals can be described as socioeconomic spaces with multi-faces on the landside and seaside.

The critical importance of container ports around the world for global supply chains has been analyzed in several research studies (Wang and Cullinane 2015). According to (Wang and Cullinane 2015) a container port is simply an element or actor, among a number of actors, in the import or export supply chain connecting the producer to the consumer. However, ports become a complex environment, according to Notteboom, TE, & Langen, PW (2014), the globalization of production and consumption, the emergence of a global transportation network and the evolution of port relationships, port-hinterland relations and logistics have created increased competition between ports.

* Corresponding author email address: kaoutar.douaioui@gmail.com
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Therefore, in order to meet the demands of international trade and supply chains, ports need to be able to accommodate and manage larger ships faster and larger inland hinterland modes. As a result, port construction, expansion, planning and management are becoming more complex and costlier. The complexity of port terminals represents a challenge to their performance, which explains the development of performance measurement systems at port terminals or the whole dry port-sea port system. This aspect is also complex and poorly studied. (Bentaleb et al. 2016) propose a review on the different models developing this system and (Bentaleb, Mabrouki, and Semma 2015) aimed to evaluate the performance indicators of the system based on Multi-Criteria Decision Making (MCDM) approach. The MCDM approach is a sub discipline of operations research that conduct to facilitate for decision-maker to have the best alternative from different information from multiple criteria. There are many methods based in MCDM. The most used methods are based on the judgments of decision-makers, therefore these methods suffer from inconsistencies caused by different judgments. (Aguarón, Escobar, and Moreno-Jiménez 2021) aims to reduce inconsistency in the analytic hierarchy process using geometric consistency index, however most of the methods still suffer from inconsistency.

This paper aims to evalute efficiently the performance level in the port container terminal by reducing inconsistencies; this study will combine the MACBETH method (Measuring Attractiveness by a Categorical Based Evaluation Technique) and DELPHI method. The paper is divided into five sections: The second section explains the study context of the performance in port container terminals. The third section identifies the objectives of the performance measurement system, the performance measures and the sub-indicators affecting the system. The fourth section propose a novel framwork composed by the DELPHI and MACBETH tools to reduce the inconsistencies in evaluation of the the proposed performance measurement system. In the fifth section, the PMS is applied to four case studies: the port container terminal of Havre, the port container terminal of Casa Port, the port container terminal of Tanger-Med and the port container terminal of Rotterdam. The conclusion in the sixth section closes the model and shed light on the perspectives.

2. Problem Description

2.1 Methodology

The project begins with reading the states of the art in order to redefine the concept of global port performance. Then, comes the development of the model, which is based on three main ideas: i) A four-level horizontal interaction model; the first level aims to evaluate the overall performance, the second aims to evaluate the various objectives of the port container terminal, when the third level determines the performance indicators and the fourth level contains the performance sub-indicators. ii) An overall evaluation resulting from all the objectives of the evaluated organization. iii) The non-obligation to define a weight of each indicator belonging to the fourth level. It is sufficient to determine the interaction between the levels of each indicator and the interaction between the different indicators. To do this, the multi-criteria analysis tool MACBETH compare the different scenarios defined by the decisions taken.

2.2 Problem Description

Zhu assumes that it is difficult to assess the performance of an organization when there are several performance measures related to a system or operation (Zhu 2014) , including several organizations in the case of port terminals. Whereas the growing competitiveness in the port need a higher level of performance.

Over the past decades, many researchers have been studying the evaluation of the efficiency and performance of port terminals, particularly those of container ports and terminals. Some researchers have addressed the theory and methodologies of port and terminal assessment and measurement of performances (Estrada, Jenatabadi, and Chin 2017; Roll and Hayuth 1993; V.F.Valentine and R.Gray 2011; Cullinane, Song, and Gray 2002; Notteboom, Coeck, and Broeck 2000a; Cullinane, Teng, and Wang 2005; Panayides and Lun 2009) including classification research.

Many recent studies have focused on regression methods, data envelopment analysis (DEA) (Fereshteh 2018) and MCDM (Sahin and Soylu 2020) . These methods have been used more to compare and analyze port performance. A detailed survey for each DEA technique is provided by (Estache, González, and Trujillo 2002; Odeck and athen 2012). Otherwise, the interesting study aims to optimize the port performance using optimization algorithm and machine learning (Fri, Douaioui, Lamii, et al. 2020c; Fri, Douaioui, Tetouani, et al. 2020; Fri, Douaioui, Lamii, et al. 2020a; 2020b)

This diversity puts port terminal managers in front of dozens of performance measurement systems. Furthermore, each port has a particular social, economic and environmental specificity. Faced with this difficulty, ports are choosing performance measurement systems, which hide the port weaknesses and emphasizes their strengths; for example, there are ports that were partners in the PPRISM (Port Performance Indicators Selection and Measurement) and are still working with their own performance indicators.

In addition to the multifarious problems of performance measurement systems, the lack of a reliable methodology and identification of key performance indicators affect transparency in the standard measurement; consequently, these indicators become insignificant. The project (Organization 2012), launched by the European Union in partnership with a dozen port terminals in Europe, aim s to cover this shortcoming by identifying standardized indicators. Canada also launched a project Port Terminal Usage Indicators, but many port terminals in Europe and Canada continue to use their own indicators.

These works show that research on the theory and methodologies of port, terminal efficiency, performance evaluation and measurement have been constantly evolving and progressing (Ju and Liu 2015).

Port terminals are complex environments where different logistic actors interact at different levels. However, most of the works target a single type of performance, either physical or financial, or targets the overall performance. These articles (Suwignjo, Bititci, and Carrie 2000; Garengo, Biazzo, and Bititci 2005) highlight the surprising lack of research that aims at determining overall performance by taking all port stakeholders into account. All this motivated us to fill this gap by this work.

3. Performance Measurement System

3.1 Aims of the Performance Measurement System

The performance measurement system mainly depends on the overall aims of the company (Lima, Costa, and Faria 2009), which leads us to determine the aims of the port terminals.

Most companies give more importance to financial performance since the objective of each organization is to create profits, which explains the existence of financial performance in all the performance measures proposed by the port terminals and the International organizations. As a result the financial performance is primary aim in overall performance.

But it is surprising that port managers continue to neglect operational and logistical performance. Therefore, (Bichou and Gray 2004) criticizes the approaches adopted by ports and researchers who neglect the logistic side despite the primary role of the port terminal in the global logistic chain. Also, Mabrouki et al. considers that the optimization of operations in port terminals is very important (Mabrouki, Bentaleb, and Mousrij 2014). Therfore, it is judicious to focus on operational and logistical performance.

Several organizations classify ports according to their size, in particular the surface area of ports, lengths and platform infrastructure. Cruz et al. have shown that physical performance contributes to 51.23% of total performance (Cruz, Ferreira, and Azevedo 2013); this is why the physical performance is the main component of overall performance.
In addition to those objectives, there is a need to improve trade performance, as shipping is correlated with the economic developments and the performance in international trade.

Generally, the supply chain is linked to the marketing of a product and service. According to Cheyroux, a supply chain is defined as follows: "It is a network of sites, independent or not, participating in the procurement, manufacturing, storage and distribution activities related to the marketing of a product or service" (Cheyroux 2003).

3.2 Financial Performance

Financial measures are considered as urgent goal in all manufacturing companies (Javad and Alireza 2018), particularly in the port area. This is due to the economic and financial impact of ports historically known on the economy of countries. Güner argue that the financial efficiency is one of the four types of efficiency in the seaport (Güner 2015).

Among the financial performance indicators, the financial health reflects the balance of the organization as well as its ability to face a recession. These works (Brooks and Pallis 2008; Organization 2012) based their research on this pillar to assess port performance.

Indeed, financial performance reveals the success of a company, its profitability and its growth, which are reflected in financial wealth. Thus, investment is at the top of all performance measurement as it generates over 90% of added value. Many authors link the performance of the maritime terminal to the relevance of the investment(Langen, Nijdam, and Horst 2007; Rankine 2003; Lagneaux 2006; Bichou 2006; Organization 2012).

3.3 Physical Performance

The physical performance concerns the performance of physical resources, equipment and the facilities.(Aimadedine Belkhiri 2016) assumes that the best performing ports are those that manage to control the entire supply chain by integrating upstream and downstream the different physical and information flows. According to this, physical performance depends mainly on i) port size ii) material performance iii) the exploitation of technology.

Port sizes are emphasized in many research and classification works (Ng and Vaggelas 2012). They reflect the capacity of the port and directly impact its competitiveness.

The physical performance evoked by (Barzman 2012) is essential to performance analysis. The physical performance increase the productivity of the port terminal by increasing the availability and reliability of the equipment.

The exploitation of technology ensures continuous development within the port. It directly influences the effectiveness of the port in terms of the transit. Speed this is why it has attracted the attention of several researchers like (Martino et al. 2013; Estrada, Jenatabadi, and Chin 2017).

3.4 Commercial Performance

In recent years, the commercial competitiveness of container terminals has been exacerbated by the competitiveness of port container terminal.In fact commercial performance in the supply chain of port terminals is attracting more and more customers. In addition Bédé and Lorek shows the importance of the strategic position (BéDé 2013; Lorek 2012). Furthermore we highlight the consequence to add security / safety which is also selected by (Organization 2012).

On the other hand, the strategic position is a decision related to the planning and management of the terminals. A strategic position of port terminals will minimize transportation costs to the major markets to be served.

3.5 Operational and Logistic Performance

Bichou affirms that financial performance does not imply efficient and effective use of resources, the financial performance does not imply the effectiveness of the management and operation system (Bichou 2006). It is therefore important to measure operational and logistical performance. UNCTAD has also selected a set of indicators designated for the operational results category. According to this, operational and logistic performance depends mainly on i) Administrative management ii) Management of ship service iii) Management of quay operations iv) Yard Operations, v) employee performance.

The efficiency in port management is very essential to satisfy the interaction between different actors, given its importance it is one module of the World Banks Port Reform Toolkit.

Asuquo et al. confirms that The Management of ship service present some challenges to both shipping companies and ship owners (Asuquo, Coward, and Yang 2014), and this challenge must be affronted by an awareness management plan. The management of quay operations is the weakest link in all operations of the terminal container, which motivated us to consider a key driver in the proposed PMS.
Yard management represents many complex challenges to yard manager (Carlo, Vis, and Roodbergen 2014). These challenges are due to the evolution if the international commerce, this is why we will evaluate this performance.

Thus, we have selected the employee’s performance since this performance is essential in most of tasks in industries; and in ports particularly.

3.6 The Global Performance Measurement System.

This work presents the objectives to be achieved to have a global performance of the container terminal as well as the performance indicators involved in achieving these objectives.

When identifying the performance indicators mentioned in the literature, the organizations (ESPO, UNCTAD ...) and the reports of the port terminals, we have selected about 312 indicators. The first selection is based on the five criteria provided by the work of the Literature illustrated in Table 1. Finally, a critical study on each indicator is done by i) eliminating redundant indicators i) grouping indicators of the same type iii) keeping the indicators influencing operational performance. Figure 01 illustrates the three-stage selection methodology. On the last stage, the list of performance indicators is limited to 47 indicators that synthesized in table 2 containing the references of each indicator and its description. Next, Table 3 presents the overall performance measurement system containing all system components including the sub-indicators that constitute the performance indicators.

Criteria	Description
The relevance of policy	Monitor the strategy and progress of the activity
Informative	Provide relevant information to the activity
Measurable	Measure following a reliable procedure
Representative	Gives information simple to interpret
Practical	Simple to monitor

Table 1. Criteria for selecting performance indicators.

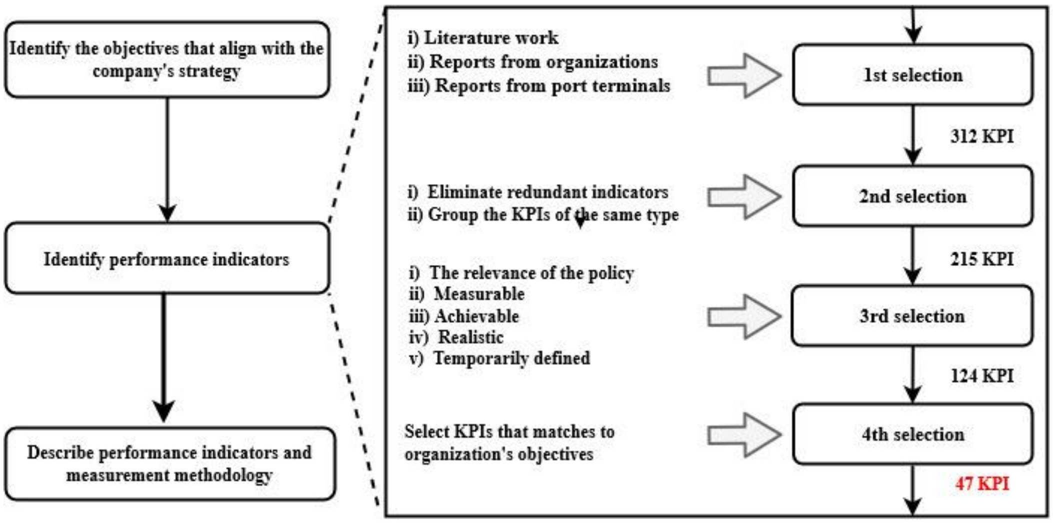

Figure 1. Approach to identifying and selecting performance indicators.

Table 2. The description of sub-indicators of the performance measurement system.

Indicator	Description	Reference
Direct employment rate	Jobs created through direct employment	(Organization 2012)
Indirect employment rates.	Refers to jobs directly related to the production of products or services.	(Organization 2012)
Direct Gross added value	Volume of business generated by the sale of goods, manufactured products, services provided by the organization	(Organization 2012)
Indirect Gross added value.	Volume of the generated services and that is impacted by the sale of goods, products manufactured, services provided by organizations in relation to the company	(Organization 2012)

Table.2. Continued

Indicator	Description	Reference
Liquidity	Represents the funds available immediately	(Ha, Yang, and Heo 2017)
Profitability	The ratio between discounted cumulative cash flows and invested capital.	(Ha, Yang, and Heo 2017)
Solvency	Provides information on the ability of the company to pay all of its financial commitments in the case of liquidation.	(Urciuoli et al. 2013)
Short-term investment	An investment is an expense to positively alter the business cycle of the organization within a period of approximately one year.	(Willan 2013)
Medium-term investment	An investment is an expense to positively alter the business cycle of the organization within a period of approximately two, three years or more	(Willan 2013)
Long-term investment	An investment is an expense to positively alter the business cycle of the organization within a period of approximately ten years or more	(Willan 2013)
Terminal size	Represents the size of the port terminal in square meter	(Langen, Nijdam, and Horst 2007)
Draft	Measures the vertical distance between the waterline and the keel (the lowest point of the hull)	(Talley 2006; Yeo, Roe, and Dinwoodie 2008; Tongzon and Heng 2005)
Length of the quay	Represents the length of the quay in meter	(Notteboom, Coeck, and Broeck 2000a) (Notteboom, Coeck, and Broeck 2000b)
Number of Gantries	The number of gantries in the port terminal	(Langen, Nijdam, and Horst 2007)
Number of Quay Crane	Number of quay crane in the port terminal	(Langen, Nijdam, and Horst 2007)
Number of Reach stacker	Number of Reach stacker in port terminal	(Langen, Nijdam, and Horst 2007)
Exploitation of Electronic Data Interchange	The effectiveness of computerized communication between the different stakeholders of the port terminal	(Talley 2006; Yeo, Roe, and Dinwoodie 2008; Tongzon and Heng 2005)
Location & tracing of ships	Measures the availability and effectiveness of ship tracking and tracing technologies	(Talley 2006; Yeo, Roe, and Dinwoodie 2008; Tongzon and Heng 2005)
The degree of automation of cranes	Represents the level of performance of technical tasks by machines operating without human intervention	(Talley 2006; Yeo, Roe, and Dinwoodie 2008; Tongzon and Heng 2005)
The reliability of the services offered	Measures the reliability of the services offered by the port terminal	(Langen, Nijdam, and Horst 2007; Cullinane, Teng, and Wang 2005)
The concentration of maritime traffic	Measures the number of ships passing through the vicinity of the port terminal.	(Langen, Nijdam, and Horst 2007; Organization 2012)
Market shares	Measures the market shares captured by the port terminal in relation to the potential market.	(Alix 2011)
The concentration of land-side traffic	Measures the proximity of the port terminal to industrial areas	(Organization 2012)
Safety	The guarantee to have a physical protection of the personnel as well as the protection of the goods and services of the company.	(Mohamed-Chérif and Ducruet 2011)
Operational Security	Measures the criticality of work accidents causing material damage	Langen, Nijdam, and Horst 2007)
Professional Security	Measures the criticality of work accidents causing human damage.	(Wiegmans, Hoest, and Notteboom 2008)
Traceability and verification of instructions	Elapsed time to verify a command or information in the port terminal	(Ng and Vaggelas 2012)
The effectiveness of customs procedures	Demonstrates the speed, reliability and effectiveness of customs procedures at the port terminal	(Organization 2012)

Table 2. Continued

Indicator	Description	Reference
The agility of procedures	Represents the flexibility and elasticity of procedures at the port terminal.	(Tongzon and Heng 2005)
Administrative coordination	Degree of agility during coordination between admiration operations.	(Ha, Yang, and Heo 2017)
Towing Efficiency	Measures the availability and effectiveness of the vessel towing at the port terminal.	(Walkenhorst and Yasui 2009)
The effectiveness of piloting	Measures the availability and efficiency of the vessel steering in the port terminal.	(Zaoudi, Ihadiyan, and Zouiri 2015)
Turnaround time	Measures the time between the arrival of the ship and its departure from port terminals.	(Zaoudi, Ihadiyan, and Zouiri 2015)
The effectiveness of bunkering.	Measures the availability and efficiency of bunkering in the port terminal.	(Cullinane, Song, and Gray 2002)
Effectiveness of the coordination of operations	It represents the effectiveness of coordination between operations.	(Ha, Yang, and Heo 2017)
Centenaire maintenance	It represents the performance of container maintenance in the port terminal.	(Zaoudi, Ihadiyan, and Zouiri 2015)
Availability of rider trolleys	The ability of rider trolleys to perform during working hours at the port terminal.	(Wiegmans, Hoest, and Notteboom 2008; Lacoste and Bouchet 2012; Brooks and Pallis 2008)
The Operational productivity (TEUS/H)	It shows the speed and efficiency of the gantry cranes.	(Wiegmans, Hoest, and Notteboom 2008; Lacoste and Bouchet 2012; Ju and Liu 2015; Brooks and Pallis 2008)
The quay occupancy	It represents the time during which the quay at the port terminal is occupied by vessels.	(Lacoste and Bouchet 2012; Wiegmans, Hoest, and Notteboom 2008; Brooks and Pallis 2008)
Average truck loading time	The average time required to load a truck completely.	(Flécher 2014)
the availability of trucks	The ability of trucks to perform their duties during working hours at the port terminal	(Burdeau 2015)
Truck utilization rate	Ratio of truck operating over truck availability.	(Davydenko, Jordans, and S 2007)
The stacking height	The average number of containers per stack.	(Rekik, Elkosantini, and Chabchoub 2017)
The percentage of employees that have more than five years' experience.	Informs about the percentage of qualified personnel working in the port terminal.	(Thai 2012)
The number of hours of training per employee	The amount of training hours that have been organized for the benefit of each employee	(Thai 2012)
The number of errors due to the human factor	The average number of errors committed by employees.	(Thai 2012)

Table 3. The global performance measurement system.

Aims	Indicators	Sub-indicators
Physical performance	**Port size**	• Terminal area.
		• Draft.
		• The length of the quay.
	Port equipment	• Number of Gantries.
		• Number of quay crane.
		• Number of Reach stacker.
	The exploitation of technology	• Exploitation of Electronic Data Interchange.
		• Location & tracing of data.
		• The degree of terminal automation.
Financial performance	**Financial wealth**	• Indirect employment rate
		• Direct employment rate
		• Direct turnover
		• Indirect turnover
	Financial health	• Liquidity
		• Profitability
		• Solvency
	Investment	• Long-term investment
		• Medium-term investment
		• Short-term investment
Operational and logistical performance	**Administrative Management**	• Traceability and verification of instructions
		• The effectiveness of Customs Procedures
		• The agility of procedures
		• Administrative Consolidation
	Management of ship services	• Towing Efficiency.
		• The effectiveness of piloting.
		• Turnaround time.
		• Bunkering Efficiency
		• Effectiveness of Operations Coordination.
		• Container maintenance.
	management of quay operations	• Availability of rider trolleys.
		• The operational productivity (TEUS/ hr).
		• The quay occupancy.
	yard operations	• Average truck turns times.
		• The availability of the truck.
		• Truck utilization rates.
		• The stacking height.
	Employee Performance	• The percentage of employees that have more than five years' experience.
		• The number of hours of training per employee.
		• The Number of errors due to the human factor.
Commercial performance	**Services and Organizations**	• The Reliability of services offered.
	Competitive Positioning	• Concentration of maritime traffic.
		• Market Shares.
		• Concentration of land-side traffics.
	Safety and Security	• safety.
		• Professional Security.
		• Operational Security.

4. The proposed framework

The development of a PMS is not the ultimate goal, it is more important to have a successful implementation of the company. So, there are multiple frameworks but the majority of them are based on expert's judgments, which remains a weakness since if experts are made a wrong judgment, PMS will generate a misleading conclusion. Thereby,the proposed framework reduces inconsistency by using the DELPHI and MACBETH tools; i) DELPHI ensures consensus between decision-makers in order to eliminate possible inconsistency when eliciting judgments, ii) MACBETH identify inconsistency judgments that should be modified and propose alternative possible judgments. The figure 2 contains the proposed framework.

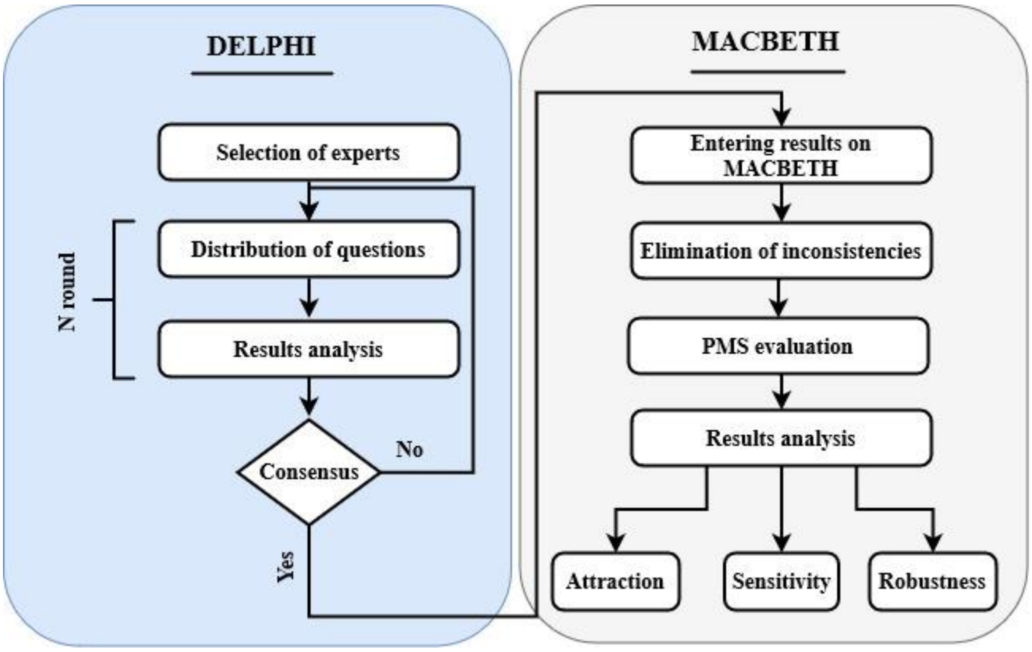

Figure 2. Decision support to avoid inconsistencies

4.1 DELPHI technique

The Delphi technique was developed by (Dalkey and Helmer 1963)at Rand Corporation. The Delphi process is a structured methodology for obtaining the opinions of several experts who are subjected to a series of intensive questionnaires taking into account the feedback of other experts. Interviewees do not engage in a discussion among themselves, thus they avoid direct discussions. During a Delphi survey, experts participate in an iteration of questionnaires. After each round, they are allowed to consult the intermediate results and have the opportunity to re-examine their judgment on the basis of the judgment of the other experts during the rounds of questionnaires (Linstone and Turoff 2011). The number of rounds of the Delphi method depends on the convergence of the judgments of the experts. In this case, eight experts are selected; five are researchers and three managers of port, the experts evaluate and determine the interaction between the different criteria.

4.2 MACBETH method

The evaluation of the global performance must take into account all criterion and the interaction between different criterion. To achieve that, using MACBETH method (Costa, Corte, and Vansnick 2012; Costa and Chagas 2004) is the most adequate to evaluate the proposed PMS.

MACBETH is a Multi-criteria decision making (MCDM) approach to assist decision-makers to quantify the attractiveness of options for each criteria, The power of methods that the decision maker is not mandatory to define the weight of the performance measure to assess.

However, it aims to justify and transform semantic judgments between two elements at a time. After entering the judgments to MACBETH software, the software detects automatically eventual inconsistencies in the judgments of experts and generate a weight of each criteria. Moreover the Macbeth software provides a tool to analyze deeply the sensitivity and the robustness.

The model will be evaluated in four steps with the fruitful collaboration of eight experts in performance of the terminal container : the first step is to determine the performance sub-indicators based on data collected from the port container terminal to be evaluated. The second step consists in using expert judgment based on the MACBETH tool to evaluate the indicators on a scale of 1 to 5. The third step consists in determining the main aims of this model on a scale from 1 to 7 using MACBETH and the last one evaluates the global performance on a scale from1 to 9 that is given in table 04.

Table 4. Nine-point scale used in rating performance

Performance level	Verbal Meaning
1	Extremly low level
2	Very low level
3	Low level
4	Moderate level
5	Good level
6	Very good level
7	Hight level
8	Very hight level
9	Excellent level

5. Results Analysis

After filling in the experts judgments of the port terminal of Casa Port in Macbeth software, MACBETH software build the global result look like ulustrate in figure 3. MACBETH software provide a sensitivity, attractiveness and robustness analysis in order to have a deeper understanding and a validation of the model.

Table of scores

Options	Overall	PP	FP	OLP	BP
L 1	0.00	0.00	0.00	0.00	0.00
L 2	15.44	17.65	12.50	14.29	12.50
L 3	48.03	29.41	80.00	57.14	37.50
L 4	78.55	64.71	92.50	95.24	100.00
L 5	82.96	70.59	100.00	100.00	75.00
L 6	87.08	100.00	72.50	71.43	75.00
L 7	64.84	70.59	62.50	42.86	68.75
L 8	45.18	52.94	35.00	33.33	50.00
L 9	30.66	41.18	17.50	19.05	25.00
[all upper]	100.00	100.00	100.00	100.00	100.00
[all lower]	0.00	0.00	0.00	0.00	0.00
Weights :		0.5294	0.2941	0.1177	0.0588

Figure 3. Table of scores of global performance.

The difference between the profiles of any two levels can be viewed by difference profiles. Let us observe that each criterion bar in the weighted profile of the global performance. For example, in Figure 4 the level L4 is compared to the level L9. The level L4 out performed overall level L7 with 13.71 score points. However, the level L7 out performed in package L4 with regards to the physical performance with 3.11 score points. The weighed bars allow analyzing the extent to which the differences in favor of the one issue compensate, or not, the differences of the other issues.

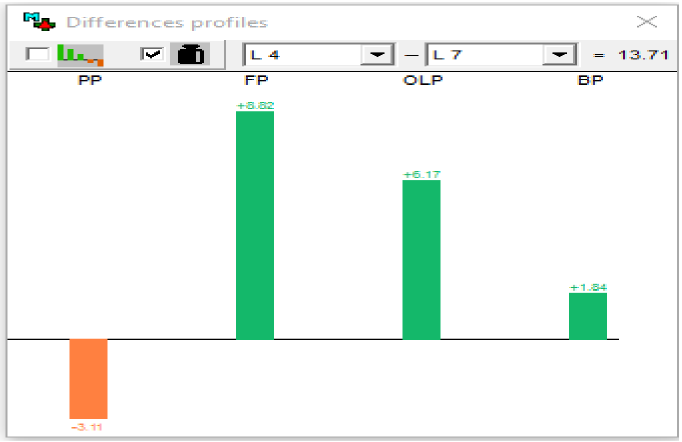

Figure 4. Differences between the profiles of levels

5.1 Sensitivity analysis.

Sensitivity analysis aims to calculate the uncertainty in output influenced by the uncertainty applied to the input. MACBETH software provides a tool to analyze the sensitivity for example figure 5 show sensitivity analysis of physical performance and make clear the intersection of L3 and L7. L3 become higher ranked than L7, if the weight of criteria physical performance is less than 20.5 (the weight of physical performance must decrease by 33.44%).

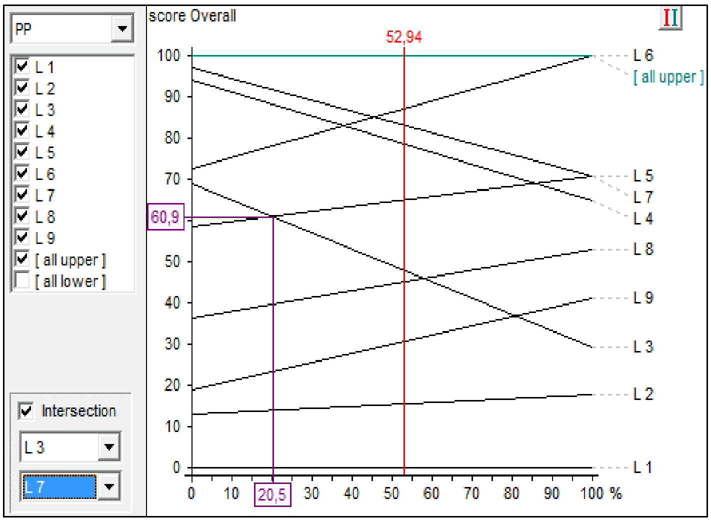

Figure 5. sensitivity analysis of physical performance

The table 4, 5, 6 and 7 show the overall results of the sensitivity between the different level of performance of the proposed system respectively for physical performance, business performance, operational and logistic performance and the commercial performance.

The given key facilitates the understanding of the tables 5-8:

- O : at the intersection of L 2 and L1 means that L2 perform L1 (see figure 01).
- U : at the intersection of L 9 and L8 means L9 underperform L8(see figure 01).
- U If Wp > 20.5: at the intersection of L7 (Line) and L3 (Column) means that L7 underperform L3 if weight of physical performance upper 20.5 (see figure 01).

With

- Wp : weight of Physical Performance
- Wb : weight of Business Performance
- Wol : weight of operational and logistics Performance
- Wc : weight of commercial Performance
- O : outperform
- U : underperform

Table 05. Sensitivity analysis of Physical Performance

Wp= 52.94	**L1**	**L2**	**0**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
L1									
L2	O								
L3	O	O							
L4	O	O	O						
L5	O	O	O	O					
L6	O	O	O	O if Wp >37.9	O if Wp> 45.3				
L7	O	O	O If Wp > 20.5	O if Wp>85.9	U	U			
L8	O	O	O if Wp > 58.0	U	U	U	U		
L9	O	O	O if Wp > 81.0	U	U	U	U	U	

Table 06. Sensitivity analysis of Business Performance

Wb= 29.41	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
L1									
L2	O								
L3	O	O							
L4	O	O	O						
L5	O	O	O	O					
L6	O	O	U if Wb > 88.6	U if Wb > 50.6	U if Wb > 38.6				
L7	O	O	U if Wb > 64.0	U	U	U			
L8	O	O	U if Wb > 24.6	U	U	U	U		
L9	O	O	U if Wb > 2.2	U	U	U	U	U	

Table 07. Sensitivity analysis of Operational and Logistical Performance.

Wol= 11.17	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
L1									
L2	O								
L3	O	O							
L4	O	O	O						
L5	O	O	O	O					
L6	O	O	O	U if Wol > 35.1	U if Wol >22.9				
L7	O	O	U if Wol > 59.5	U	U	U			
L8	O	O	U	U	U	U	U		
L9	O	O	U	U	U	U	U	U	

Table 08. Sensitivity analysis of Commercial Performance

Wc= 11.17	L1	L2	L3	L4	L5	L6	L7	L8	L9
L1									
L2	O								
L3	O	O							
L4	O	O	O						
L5	O	O	O	U if Wc > 20.3					
L6	O	O	O	U if Wc > 30.2	U				
L7	O	O	O	U	U	U			
L8	O	O	O if Wc > 23.3	U	U	U	U		
L9	O	O	U	U	U	U	U	U	

5.2 Attractiveness analysis

The attractiveness analysis provides decision makers the efficient recommendations. The analyzing of the attractiveness between criteria and levels can be made by using a two-dimensional graph (XY Map), where each axis represents the global performance.

In the figure 6, the levels are presented according to their attractiveness on the financial and physical performance. According to graph the package L3 has a good financial condition but is not attractive on the physical performance. On the other hand, the level L7 has an equal attractive financial and physical conditions. In the red line which represents the efficient frontier as a result, L5 and L6 as a dominate levels.

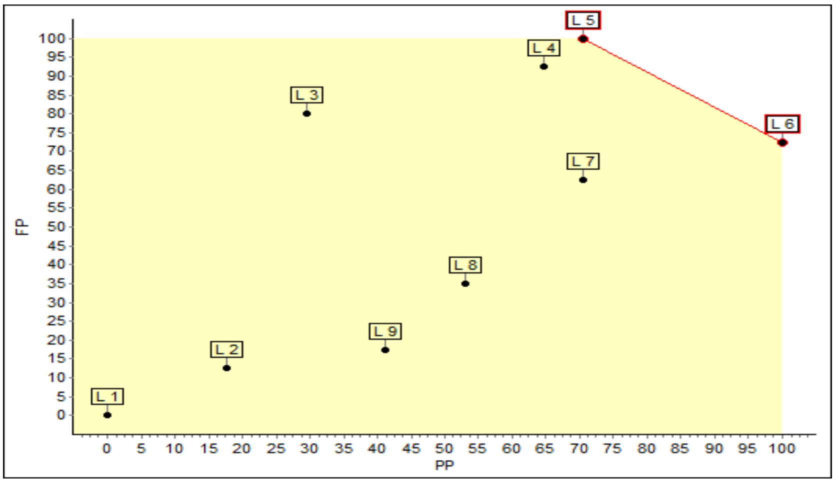

Figure 6. Attractiveness analysis between Business Performance (FP) and Physical Performance (PP)

5.3 Robustness analysis

The robustness of the results was also tested by using the respective function of the M-MACBETH software ("Robustness analysis"). The figure 7 showed that a simultaneous change of up to 5 value points across all of the attribute reference levels would not impact the ranking of the alternative levels

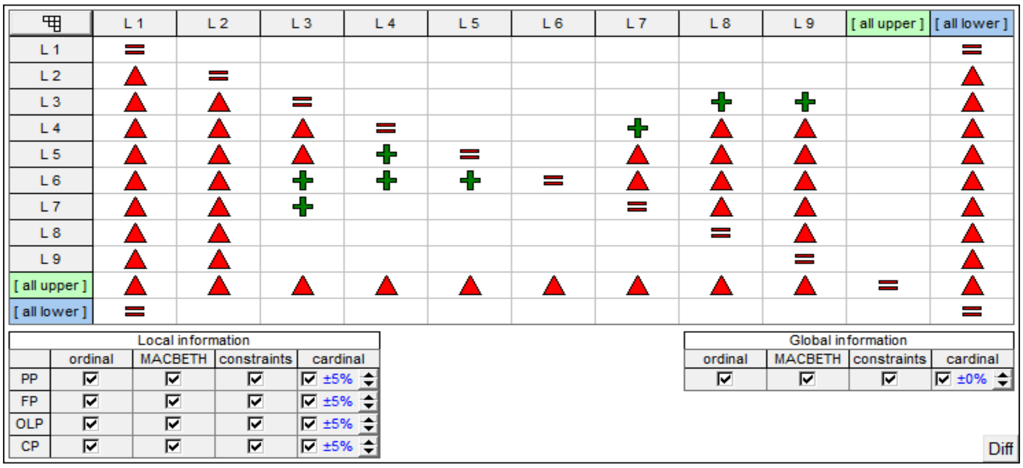

Figure 7. Robustness analysis of Global Performance

5.4 Discussion

We applied the same approach in the three port container terminals: the port terminal of Rotterdam, the port terminal of Tanger Med and the port terminal of Havre. This allows us to have results that validate the model and make the necessary assessment in order to improve the overall performance. (Table 9) This model allowed us to determine a weight for each aim of the performance measurement system. For the four ports, the weights vary between 0.47 and 0.53, which confirms the conclusion of (Cruz, Ferreira, and Azevedo 2013) who argued that the physical performance contributes to 51.23% of total performance.

Checking the sensitivity of model is made by varying the weight of each objective by 5% therefore any disturbance in results that proof the sensitivity of models.

In the same way to check the robustness of this model, there must be no impact on the ranking of the alternative levels if we apply a simultaneous change of up to 5 value points across all of the attribute reference levels. The table shows the global performance of four cases studies and the sensitivity and the robustness analysis.

Table 9. Description of the sub-indicators of global performance measure system

Port container terminal	Global performance of 9	Sensitivity	Robustness
Rotterdam container terminal	8	Stable	Robust
Tanger Med container terminal	7	Stable	Robust
The container terminal at Havre	7	Stable	Robust
The container terminal at Casa Port	6	Stable	Robust

.

6. Conclusions and future works

This work provides a performance measurement system for port container terminals. This system can be used to make a benchmarking between different port container terminals, to evaluate them, and to detect if the tendency of performance is going higher or lower and to determine the improvements to be made. Most of the models currently available are based on the judgments of experts, which can distort the study in case of a bad evaluation of an expert. On the other hand, this model detects all the inconsistencies during the judgments of the experts and proposes the most consistent judgments.

As a perspective, it is essential to have a reliable methodology to measure and identify the key performance indicators. With different methods of measurement and identification, these indicators became insignificant. Consequently, this work must be done in this direction in order to standardize the measurement methods as well as performance indicators. In addition, all current models are static and do not take into account the interaction and influence between the different components of the performance measurement system, therefore the development of a dynamic performance measurement system is required.

In fact, an update of performance measurement systems is mandatory to deal with the fast changes in ports. Today, the implementation of industry 4.0 in all sectors increase the data availability in real time which needs new infrastructure (Mamad 2018) , so it is judicious to develop a dynamic Performance Measurement System connected automatically in different sensors to the port.

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