

# A Holistic Modeling Framework for Operational Excellence in the Automotive Industry: An Integrated Perspective on Technical Systems and Human Dynamics

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## ABSTRACT

This study is dedicated to the empirical evaluation and validation of the way the implementation of operational excellence practices affects the performance of companies operating in Morocco, with a focus on technical systems and human dynamics in the automotive sector and within the application of a holistic operational excellence perspective. A structured questionnaire was administered to 264 firms, yielding a 93% response rate (246 usable responses), ensuring sector representativeness. The robustness and relevance of the measurement tools were rigorously evaluated, and the statistical processing of the data was carried out using the SPSS version 28 software. Integrating technical and human aspects for operational excellence in the automotive industry, this study highlights that both "soft" (employee engagement, culture) and "hard" (basic continuous improvement tools) factors significantly impact performance. While fundamental "hard" practices are understood, advanced tools are less effectively implemented. Achieving holistic operational excellence requires a balanced investment in both human development and a wider, more effective application of improvement methodologies. This study's results, based on a holistic model integrating technical and human dimensions of operational excellence, offer practical recommendations for long-term competitive improvement. They also provide a valuable empirical basis for understanding the concrete impact factors of this integrated approach in an under-represented industrial setting, namely the Moroccan automotive industry, thereby validating existing theoretical frameworks in a specific contextual application.

*Keywords-automotive industry; operational excellence; critical success factors; critical failure factors; leadership*

## I. INTRODUCTION

The contemporary economic environment is characterized by increasing complexity, rapid dynamics, and high uncertainty, which has significant implications for businesses and their pursuit of Operational Excellence (OE) [1]. Faced with exacerbated volatility due to events like the COVID-19

pandemic [2], companies must cultivate organizational agility to adapt quickly to market changes [3]. Digital transformation is an imperative, requiring investment to improve efficiency, productivity, and innovation capabilities [4]. Furthermore, environmental and social concerns, with the growing importance of ESG (Environmental, Social, and Governance)

criteria, are becoming central to the evaluation of performance and sustainability [5]. By aligning with these objectives, OE strengthens resilience to market volatility while creating sustainable value for stakeholders. In this context, OE, based on continuous improvement, process optimization, a dedicated organizational culture, and rigorous performance measurement, is essential for business competitiveness and sustainability [6].

OE fundamentally relies on integrating technical systems and human dynamics to optimize processes, boost productivity, and ensure sustainable performance [7]. Technical systems, including infrastructure and technologies, are essential for automation and efficiency [8], while human dynamics, such as employee skills, teamwork, and organizational culture, are vital for innovation and adaptability [9]. Approaches like Sociotechnical Systems (STS) theory, Lean Six Sigma, and the use of Digital Twins highlight the need to align these two dimensions for optimal performance [10]. OE is broadly understood as a holistic endeavor demanding a strategic combination of both tangible and intangible elements. These are commonly categorized as "hard" and "soft" factors, respectively [11]. While hard factors provide the concrete infrastructure and processes, soft factors ensure the human element effectively drives continuous improvement and adaptability [7]. In today's rapidly evolving business environment, a focus on both is essential for achieving and sustaining OE [12].

In a constantly evolving global economic landscape, the Moroccan automotive industry faces increasing challenges, including heightened competition, market volatility, new regulations, climate change, and technological advancements. These factors make OE a key driver for boosting its performance and competitiveness. This rapidly expanding sector, with the establishment of new factories, presents an ideal environment for implementing an excellence model tailored to local specificities. Morocco has significantly improved its global standing, moving from 30th place in 2020 to 24th in both 2023 and 2024 [13]. The maturity of OE and its level of deployment in Moroccan Automotive Companies were studied in [14]. This progress, driven by a 4% increase in production between 2023 and 2024 (reaching 559,645 units) and ranking it 6th globally for annual growth, solidifies its role as an emerging automotive industrial hub in Africa. Furthermore, the strategic alliance of transformational leadership and motivation are crucial for OE [15].

OE heavily relies on "hard" factors, which are tangible, quantifiable elements directly measurable and controllable [16]. These factors encompass systems, processes, and metrics [17]. The key "hard" factors crucial for successful OE first include technology and infrastructure. Digitalization, leveraging technologies like machine learning, IoT, big data, and blockchain, significantly enhances supply chain and operational performance by providing real-time data for optimized decision-making [18]. Optimizing manufacturing systems with advanced technologies and efficient layouts is equally vital [19]. Second, standardized processes and methodologies are fundamental. Recognized practices such as Lean, Six Sigma, and Agile are proven approaches for continuous improvement, waste reduction, and process

optimization [20]. Implementing Total Quality Management (TQM) principles, focusing on customer satisfaction, employee empowerment, and fact-based continuous quality improvement, positively impacts operational performance [21]. Standardization is also essential for performance measurement and translating strategy into operations, providing clear benchmarks for activity evaluation [22]. Third, performance measurement and metrics are indispensable. Identifying and monitoring Key Performance Indicators (KPIs) is critical for measuring and managing OE, aligning with strategic goals and revealing areas for improvement [23]. In summary, integrating these "hard" factors is imperative for the success of OE. However, it is vital to acknowledge that solely focusing on these elements without considering "soft" factors can lead to suboptimal results [24]. A balanced approach combining both is necessary for sustainable improvements. While operational excellence is definitely tied to making processes better and boosting technical efficiency, it also heavily relies on a set of human and organizational elements often called "soft factors." These less tangible aspects, like the company culture, how people communicate, employee motivation, and the development of skills, play a crucial role in making continuous improvement initiatives a success. Several studies point out how crucial ongoing training and skill development are for reaching operational excellence. Authors in [25] showed that "soft lean practices," like training, are key for successfully implementing a Lean Production System. In [26], the role of training in boosting employee engagement and, as a result, overall performance, was highlighted. These findings are backed up by the authors in [27], who show that training is a core part of effective quality management practices. Effective communication is a cornerstone of operational excellence. The mediating role of communication in the relationship between the "hard" and "soft" factors was emphasized in [26]. Clear and open communication encourages collaboration, problem-solving, and employee engagement. Authors in [28] highlighted the importance of communication within the TQM framework. Recognizing and rewarding employees are key to boosting their motivation and engagement and recognition plays a significant role in employee engagement [26, 27]. An effective performance management system helps align individual actions with the organization's strategic goals. Performance management practices have a positive impact on overall performance and consist a key dimension of OE [27, 29].

This study advances theory not by developing a new framework, but by empirically validating the interplay of well-established "hard" and "soft" factors of OE within the specific, under-explored context of the Moroccan automotive industry. While these factors are known in a global context, their combined impact and the dynamics of their implementation in an emerging market like Morocco remain underexplored. Our large-scale empirical investigation provides a nuanced theoretical understanding of the ways sociotechnical systems theory operates and drives performance in this distinctive industrial setting, thereby providing a crucial empirical validation for existing theoretical frameworks. Our research objective is to empirically confirm whether the relationship between hard and soft factors and OE holds true in the unique

socio-cultural and operational reality of Morocco. Recent research has explored the assessment of OE maturity within the Moroccan context, providing valuable comparative insights for the current study [30, 31]. This approach highlights the critical need to transition from merely applying standardized models to embracing a transformation that is deeply sensitive to context, and centered on human and organizational dynamics.

## II. EXPERIMENTAL STUDY

### A. Hypotheses Formulation

Based on the literature review, the following hypotheses were formed:

H1: Hard Factors Have a Positive and Significant Impact on OE.

H2: Soft Factors Have a Positive and Significant Impact on OE.

### B. Research Methodology

At first, the "Preliminary Study Results" are established which stemmed from literature review and analysis, exploring OE within the Moroccan sociocultural context and its application in the global automotive sector. These initial investigations led to the creation of a preliminary version of the questionnaire, which was then subjected to an in-depth review by academic experts and practitioners. The questionnaire items were generated from established scales in the OE literature and adapted to the automotive industry context. To carry out this study, a comprehensive census of all Moroccan automotive companies was first conducted. To do so, the AMICA (Moroccan Association for Automotive Industry and Trade) and the Moroccan Ministry of Industry and Trade were contacted. These institutions provided a preliminary list of 204 companies. This list was subsequently updated with greenfield companies to reach a total of 264 companies, which constitutes the entire Moroccan automotive sector. All these companies were contacted, either directly or through LinkedIn. The companies that had not responded to the questionnaire were followed up with. Subsequently, it was understood that the non-responses from certain companies were justified by the fact that they had not yet integrated OE into their strategy, due to their small size.

A pilot test was conducted with a sample of 12 industry professionals to assess questionnaire's clarity, relevance, and comprehension, leading to minor refinements before the final version was deployed. Rigorous validation was conducted using SPSS software. Data collection followed, yielding 588 responses that were processed for validity, originating from 246 distinct companies out of a total surveyed of 264 companies, representing almost the entire sector. It is important to note that the number of responses is greater than the number of companies, as several employees (directors, department heads, managers, etc.) from the same company may have responded to the questionnaire, thus enriching the perspective at multiple levels. This high participation rate represents 93% coverage of the surveyed companies in the sector. The entire process concluded with a detailed analysis of the collected data.

### C. Demographics

Regarding job roles, engineering (26%) and production (24%) stand out as the most prevalent, highlighting the industrial nature of the sector. Quality assurance (20%) and maintenance (12%) follow closely, underscoring the emphasis placed on product performance and reliability. Other functions, such as human resources, process improvement, finance, and procurement, round out the picture.

An examination of hierarchical levels reveals a significant presence of managers and engineers (51%), reinforcing the importance of operational roles within the surveyed group. Technicians (37%) and directors (8%) complete the breakdown, providing an overall view of the decision-making structure in the industry. Looking at the age of the respondents, a notable 62% fall within the 20-30 age bracket, indicating a dynamic workforce and the infusion of new skills within the sector. Those aged 30-40 constitute 31% of the sample, bringing a complementary layer of experience. The smaller proportion of respondents over 40 suggests an ongoing generational shift. The professional experience of the respondents also presents a diverse landscape. A significant 28% have less than 2 years of experience, while 43% bring more than 5 years to the table. This balance between emerging talent and seasoned professional's fosters knowledge transfers and the continued growth of the industry.

TABLE I. CHARACTERISTICS OF THE STUDY SAMPLE

Characteristic	Result	Percentage (%)
Function	Engineering	26.92
	Production	24.93
	Quality	19.78
	Maintenance	12.53
	Human Resources	5.12
	Process Improvement	6.58
	Finance	2.90
	Procurement	2.23
Hierarchical Level	Executive Management	7.22
	Supervising Manager	11.17
	Professional Staff	39.69
	Technician	21.61
	Team Leader/Foreman	16.77
	Operator	4.54
Age	20-30	61.65
	30-40	30.66
	40-50	6.69
	+50	1.00
Professional Experience	Less than 2 years	27.52
	2 to 4 years	29.21
	More than 5 years	43.27

### D. Control Variables

In line with the criteria set forth by the European Commission in 2003, companies were categorized into three sizes: Micro (fewer than 10 employees and a turnover of  $\leq$  €2 million), Small (fewer than 50 employees and a turnover of  $\leq$  €10 million), Medium (fewer than 250 employees and a turnover of  $\leq$  €50 million), and Large ( $\geq$  250 employees or a turnover of  $>$  €50 million). To gauge the length of their involvement with the OE approach, participants were asked to

specify how long they had been implementing a structured OE program. The control variables are summarized in Table II.

TABLE II. CONTROL VARIABLE 1 (N = 587)

		Number	Percentage (%)
Company Size	Micro	14	2.39
	Small	82	13.97
	Medium	62	10.56
	Large	429	73.08
Turnover	≤ 2M	25	4.26
	≤ 10M	188	32.03
	≤ 50M	140	23.85
	> 50M	234	39.86
Years of Operation	0-2 years	15	2.56
	3-5 years	39	6.64
	6-10 years	191	32.54
	11-20 years	178	30.32
	21 years and over	164	27.94

Table III highlights a geographically varied distribution of the surveyed companies, with French and Moroccan businesses making up the largest portions. This strong representation from France and Morocco suggests that the study either focused on these two markets or that these countries are particularly engaged in the area under investigation. A notable presence of Spanish (7.3%), American (8.2%), and Japanese (6.3%) companies is also observed. Other countries are represented to a lesser extent. This geographical diversity offers a compelling perspective for comparing operational excellence practices and challenges across different cultural and economic landscapes.

TABLE III. CONTROL VARIABLE "COMPANY ORIGIN"

	Country	Number	Percentage (%)
Company Origin	France	191	32.54
	Morocco	148	25.21
	USA	48	8.18
	Spain	43	7.33
	Japan	37	6.30
	Italy	27	4.60
	Germany	18	3.07
	China	12	2.04
	India	12	2.04
	Tunisia	11	1.87
	Turkey	9	1.53
	South Korea	7	1.19
	Belgium	5	0.85
	Canada	5	0.85
	Portugal	5	0.85
	Austria	3	0.51
	UK	3	0.51
	Sweden	2	0.34
	Luxembourg	1	0.17

Table IV reveals a notable split between local and multinational companies, with a clear majority being multinationals (74.8%). When it comes to ecosystems, the vehicle interior and seating sector is by far the most prominent (34.6%), closely followed by wiring (20.3%) and metal stamping (10.1%). In the context of this study, "ecosystems" represent the specific value chain segments of the automotive industry in which companies operate.

Table V presents the results of a multiple regression analysis, quantifying the impact of various control variables on

OE. Data analysis identified several key factors influencing OE within the surveyed companies. The results reveal that company size (p-value = 0.000) and turnover (p-value = 0.003) are highly significant elements, as are years in operation (p-value = 0.000), suggesting that larger and long-established companies are better positioned to achieve OE. Furthermore, the origin of the company (p-value = 0.005) indicates a slight advantage for multinational companies. Conversely, company origin (p-value = 0.467) and ecosystem (p-value = 0.993) do not show a statistically significant impact on OE in this study. The statistical model used accounts for a considerable portion of the variability in OE, as evidenced by an R-squared of 0.441 and an R value of 0.664, with an F value of 37.7, confirming the overall relevance of the model. While the R-squared value of 0.441 indicates that the combination of our independent and control variables explains a significant portion of the variance in operational excellence. This result is noteworthy and suggests that our model captures key drivers of performance within the Moroccan automotive industry. However, the remaining 56% of unexplained variance is equally informative. It underscores the inherent complexity of achieving OE and highlights that numerous other factors, not included in our model, also play a crucial role. This unaccounted-for variance could be attributed to several latent or unmeasured variables, such as specific elements of organizational culture, employee well-being, competitive pressures within sub-ecosystems, or external macroeconomic factors unique to Morocco. The high percentage of multinational companies (74.8%) also suggests that corporate strategies and global supply chain dynamics could be significant, unmeasured contributors to performance. This unexplained variance does not diminish the value of our findings but rather points to the rich, multi-dimensional nature of OE and serves as a vital call for more future research.

TABLE IV. CONTROL VARIABLES- "LOCAL OR MULTINATIONAL" AND "ECOSYSTEM" (N = 587)

		Number	Percentage (%)
Ownership	Multinational	439	74.79
	Local	148	25.21
Ecosystem	Vehicle Interior & Seating	203	34.58
	Wiring	119	20.27
	Metal & Stamping	59	10.05
	Engine & Transmission	55	9.37
	Engineering	50	8.52
	Aftermarket	42	7.16
	Batteries	24	4.09
	Exterior Systems	22	3.75
	Automotive Manufacturer	13	2.21

TABLE V. RESULTS OF TESTS ON THE IMPACT OF CONTROL VARIABLES

Control Variables	Std. coeff. β	p-value
Company Size	3.588	0.000
Turnover	2.977	0.003
Years in Operation	4.312	0.000
Origin	0.727	0.467
Local or Foreign	2.825	0.005
Ecosystem	0.009	0.993
R	0.664	
R-squared	0.441	
F	37.7	

E. Identification and Selection of Operational Excellence Attributes

The various benefits of OE were identified through a review of existing literature, employing keywords such as "advantages of Operational Excellence" and "attributes of Operational Excellence," and by consulting databases like Google Scholar and Scopus. A total of 17 attributes were selected through collaboration with experts in the field. The reliability analysis was conducted using SPSS v. 28 software. The consistency of the collected data was verified, and Cronbach's alpha coefficient was estimated at 0.727, which is considered satisfactory for this study. This result confirms that the research instrument used is reliable and consistent in its data collection. Consequently, if a research instrument consistently measures the intended traits, it is deemed reliable. Each research instrument employed in this study successfully passed reliability tests, exhibiting Cronbach's alpha values exceeding 0.7.

TABLE VI. RESULTS OF RESEARCH INSTRUMENT TESTS

Measurement Instruments and Coding	Cronbach's $\alpha$ if item deleted	Cronbach's $\alpha$
AT01_Increased Profitability	0.717	0.727
AT02_Cost Reduction	0.718	
AT03_Supply Chain Optimization	0.714	
AT04_Increased Productivity	0.704	
AT05_Process Optimization	0.712	
AT06_Waste and Environmental Impact Reduction	0.711	
AT07_Downtime Reduction	0.718	
AT08_Increased Customer Satisfaction	0.710	
AT09_Improved Product/Service Quality	0.716	
AT10_Reduced Delivery Times	0.707	
AT11_Increased Customer Loyalty	0.720	
AT12_Increased Competitiveness	0.724	
AT13_Better Adaptation to Market Changes	0.714	
AT14_Development of New Products/Services	0.720	
AT15_Improved Employee Morale	0.720	
AT16_Skills Development	0.720	
AT17_Increased Employee Engagement	0.713	

Exploratory Factor Analysis (EFA) is a robust method for studying the underlying patterns within a dataset. It allows for the simplification of complex data, the identification of connections between variables, and the construction of new, composite indicators. The outcomes of our factor analysis point to satisfactory data quality and a meaningful underlying factor structure. The Kaiser-Meyer-Olkin (KMO) measure of 0.723 suggests that the correlations between the variables are strong enough to warrant a factor analysis. Bartlett's test of sphericity, yielding a chi-square value of 2294.949 with a significance level of 0.000, firmly rejects the null hypothesis that the correlation matrix is an identity matrix. This confirms that the variables are not independent and that linear relationships exist among them, thereby supporting the appropriateness of the exploratory factor analysis we conducted.

Based on the factor analysis, a five-factor solution was selected because it successfully captures a significant portion of the total variance in the data, specifically 60.08%. These five principal components effectively summarize a large amount of the information contained within the original dataset. While

factor rotation was used to enhance their interpretability, it didn't fundamentally change the proportion of variance explained by each component. This method allows for a significant reduction in dimensionality while retaining a substantial amount of information.

The rotated factor matrix, resulting from the application of the Varimax method, clearly reveals the underlying factor structure within the data. It is evident that each variable (AT01, AT02, etc.) loads strongly onto one and only one factor, which greatly simplifies the interpretation of the components. For instance, variables AT04, AT05, AT06, and AT07 load heavily on the first factor, suggesting they measure a shared dimension. Similarly, variables AT08, AT10, and AT09 load strongly on the second factor, indicating another distinct dimension. This straightforward structure, achieved through the Varimax rotation, allows us to name and interpret each factor based on the variables most strongly associated with it.

TABLE VII. ROTATED COMPONENT MATRIX

Rotated Component Matrix ( $\alpha$ )					
	Component				
	1	2	3	4	5
AT04	0.828				
AT05	0.798				
AT06	0.772				
AT07	0.605				
AT08		0.801			
AT10		0.796			
AT09		0.695			
AT11		0.631			
AT01			0.873		
AT03			0.816		
AT02			0.744		
AT15				0.835	
AT17				0.788	
AT16				0.738	
AT13					0.797
AT12					0.730
AT14					0.665

Extraction Method: Principal Component Analysis.  
 Rotation Method: Varimax with Kaiser Normalization  
 $\alpha$ . Rotation converged in 5 iterations.

The exploratory factor analysis brought to light a significant underlying structure within the data, allowing us to simplify the dataset's complexity and pinpoint five key factors that explain company performance. These factors, derived from a Varimax rotation, are: 1) Operational Performance, encompassing variables related to the efficiency of internal processes; 2) Customer Focus, highlighting the importance of customer satisfaction and loyalty; 3) Financial Performance, reflecting the company's economic health; 4) Strategy, emphasizing the company's ability to adapt and innovate; and 5) Human Resources, underscoring the significance of human capital in overall performance. It is important to note that the operational performance factor specifically includes slashing waste and environmental impact (AT06), thus demonstrating that sustainability practices are intrinsically linked and measured as a component of OE within this study, rather than as a secondary consideration or a future implication. The correlation matrix between the initial variables and the

extracted factors confirms the relevance of this factor structure. These findings suggest that the company can boost its performance by concentrating on these five key dimensions. A more in-depth look at each factor, along with a comparison against industry benchmarks, would enable the setting of more precise objectives and the implementation of targeted corrective actions.

TABLE VIII. DIMENSION REDUCTION

Variables	Measurement Instruments and Coding
Financial Performance	AT01_Increased Profitability
	AT02_Cost Reduction
	AT03_Supply Chain Optimization
Operational Performance	AT04_Increased Productivity
	AT05_Process Optimization
	AT06_Waste and Environmental Impact Reduction
Customer	AT07_Downtime Reduction
	AT08_Increased Customer Satisfaction
	AT09_Improved Product/Service Quality
	AT10_Reduced Delivery Times
Strategic	AT11_Increased Customer Loyalty
	AT12_Increased Competitiveness
	AT13_Better Adaptation to Market Changes
Human Resources	AT14_Development of New Products/Services
	AT15_Improved Employee Morale
	AT16_Skills Development
	AT17_Increased Employee Engagement

To validate the factor structure identified by the exploratory analysis, a confirmatory factor analysis was conducted. The results of this analysis demonstrate a satisfactory fit of the model to the observed data. The chi-square test ( $\chi^2=254.32$ ,  $df=152$ ,  $p<0.001$ ) is significant, which is common for large samples. However, other model fit indices are very conclusive. The GFI (Goodness-of-Fit Index) of 0.921, the CFI (Comparative Fit Index) of 0.945, and the TLI (Tucker-Lewis Index) of 0.937 are all above the recommended threshold of 0.90, which indicates that the model fits the data well. Furthermore, the RMSEA (Root Mean Square Error of Approximation) is 0.042, a value below the 0.08 threshold, confirming that the model is parsimonious and valid. These results provide robust validation of the structure of our constructs.

TABLE IX. MODEL FIT INDICES OF CONFIRMATORY FACTOR ANALYSIS

Fit Index	Value	Acceptability Threshold
$\chi^2/df$	1.67	$\leq 3.0$
GFI (Goodness-of-Fit Index)	0.921	$\geq 0.90$
CFI (Comparative Fit Index)	0.945	$\geq 0.90$
TLI (Tucker-Lewis Index)	0.937	$\geq 0.90$
RMSEA (Root Mean Square Error of Approximation)	0.042	$\leq 0.08$

To assess the convergent validity of our constructs, we analyzed the Pearson correlations between each indicator and its corresponding aggregate measure. Table X summarizes the results for all constructs, including the dimensions of operational excellence, "hard" and "soft" practices, and continuous improvement factors. The data shows that for each construct, all indicators are strongly and significantly correlated

with their aggregate measure ( $p < 0.01$  for all correlations). The Pearson correlation coefficients range from 0.445 to 0.745, which is generally considered a moderate to very strong correlation. These results show that the indicators of each construct share sufficient common variance and measure the same latent concept. These robust findings support the convergent validity of our measurement scales, confirming that our instruments are appropriate for measuring the defined theoretical constructs.

TABLE X. SUMMARY TABLE OF CONVERGENT VALIDITY MEASURES

Construct	Variable	Pearson Correlation (r)	Significance (p-value)	Interpretation (Significant Correlation)
Cr_Financial	AT01	0.659	0.000**	Strong
	AT02	0.647	0.000**	Strong
	AT03	0.494	0.000**	Moderate-strong
Cr_Operational	AT04	0.572	0.000**	Strong
	AT05	0.492	0.000**	Moderate-strong
	AT06	0.549	0.000**	Strong
	AT07	0.523	0.000**	Strong
Cr_Customer	AT08	0.445	0.000**	Moderate-strong
	AT09	0.596	0.000**	Strong
	AT10	0.608	0.000**	Strong
	AT11	0.633	0.000**	Strong
Cr_Strategic	AT12	0.646	0.000**	Strong
	AT13	0.577	0.000**	Strong
	AT14	0.614	0.000**	Strong
	AT15	0.619	0.000**	Strong
Cr_HumanR	AT16	0.644	0.000**	Strong
	AT17	0.630	0.000**	Strong
	Cr_SoftP	SP01	0.686	0.000**
SP02		0.703	0.000**	Strong
SP03		0.657	0.000**	Strong
SP04		0.745	0.000**	Very strong
SP05		0.733	0.000**	Very strong
Cr_HardP	HP01	0.596	0.000**	Strong
	HP02	0.643	0.000**	Strong
	HP03	0.655	0.000**	Strong
	HP04	0.668	0.000**	Strong
	HP05	0.661	0.000**	Strong
	HP06	0.551	0.000**	Strong
	HP07	0.627	0.000**	Strong
	HP08	0.624	0.000**	Strong
	HP09	0.618	0.000**	Strong
	HP10	0.658	0.000**	Strong
	HP11	0.619	0.000**	Strong
	HP12	0.666	0.000**	Strong
	HP13	0.651	0.000**	Strong
	HP14	0.642	0.000**	Strong
	HP15	0.569	0.000**	Strong
	HP16	0.621	0.000**	Strong
	HP17	0.616	0.000**	Strong

\*Note: p-values < 0.01 are indicated by \*\*.

Discriminant validity was assessed using the Fornell-Larcker criterion. The results, presented in Table XI, confirm the discriminant validity of all constructs. For each construct, the square root of the Average Variance Extracted (AVE), located on the diagonal, is greater than the correlations between that construct and all other constructs in the model. This indicates that each construct is empirically distinct from the others, measuring concepts that do not overlap significantly.

TABLE XI. FORNELL-LARCKER CRITERION

	OE	SP	HP
EO	0.520		
SP	0.380	0.662	
HP	0.480	0.250	0.550

Based on what the research instrument tests revealed (as can be seen in Table XII), it appears that boosting profitability, cutting costs, making the supply chain run smoother, refining processes, becoming more competitive, adapting more easily to market shifts, rolling out new products or services, and getting employees more involved, all strongly tie into improvements in the main thing we're looking at. This suggests these factors really play a big role in achieving top-notch operational performance. However, the data from this analysis indicates that things like increasing productivity, reducing waste and environmental impact, trimming downtime, making customers more loyal, developing employee skills, and improving how employees feel at work do not seem to have a noticeable effect on that main variable we're tracking.

TABLE XII. RESEARCH INSTRUMENT TEST RESULTS

Independent Variables	Std. coeff. β	p-value
AT01_Increased Profitability	0.133	0.007
AT02_Cost Reduction	0.133	0.002
AT03_Supply Chain Optimization	0.175	0.000
AT04_Increased Productivity	-0.019	0.694
AT05_Process Optimization	0.106	0.017
AT06_Waste and Environmental Impact Reduction	0.005	0.902
AT07_Downtime Reduction	0.054	0.164
AT08_Increased Customer Satisfaction	0.033	0.472
AT09_Improved Product/Service Quality	0.072	0.075
AT10_Reduced Delivery Times	-0.037	0.420
AT11_Increased Customer Loyalty	0.053	0.175
AT12_Increased Competitiveness	0.085	0.030
AT13_Better Adaptation to Market Changes	0.107	0.010
AT14_Development of New Products/Services	0.102	0.008
AT15_Improved Employee Morale	0.007	0.869
AT16_Skills Development	0.053	0.193
AT17_Increased Employee Engagement	0.100	0.021

The findings highlight how crucial some well-known aspects of top-notch operational performance are, like cutting costs, boosting quality, and being able to roll with the punches when the market changes. What is quite interesting, though, is that some things you'd often link with being operationally excellent, such as pushing productivity higher and reducing waste, do not seem to have a noticeable effect in this specific situation.

F. Predictor Variables

Table XIII presents the reliability test results for the research instrument, focusing on Cronbach's Alpha coefficients for each item within the "Soft" and "Hard" factors of OE. These values indicate the internal consistency of the various measurement scales used in the study, where a high Cronbach's Alpha (generally above 0.7) suggests good reliability of the items. The data provided in this Table allow for an assessment of the robustness of the measures adopted to collect perceptions on OE.

TABLE XIII. RESEARCH INSTRUMENT TEST RESULTS

Variables	Measurement Instruments and Coding	Cronbach's Alpha if Item Deleted
"Soft" Factors	SP01_Recognition and Reward System	0.764
	SP02_Employee Development System & Continuous Training	0.765
	SP03_Continuous Improvement System	0.758
	SP04_Communication System	0.761
	SP05_Performance Management System	0.753
"Hard" Factors	HP01_5S	0.743
	HP02_Visual Management	0.785
	HP03_Standardization	0.742
	HP04_Problem Solving	0.749
	HP05_Single-Minute Exchange of Die (SMED)	0.740
	HP06_Takt time	0.737
	HP07_Quality Tools	0.742
	HP08_Value Stream Mapping (VSM)	0.743
	HP09_Total Quality Management (TQM)	0.754
	HP10_Poka-yoke	0.737
	HP11_Total Productive Maintenance (TPM)	0.755
	HP12_Waste Elimination	0.755
	HP13_Autonomation / Jidoka	0.736
	HP14_Pull System	0.734
	HP15_Kanban	0.732
	HP16_Just-in-Time	0.734
	HP17_Kaizen	0.737

Tables XIV and XV respectively present the ranking of "soft" and "hard" factors of OE. These rankings are established based on their Relative Importance Index (RII), a widely used statistical technique designed to quantify and prioritize the perceived importance of various factors or clusters. The RII is calculated from responses collected from respondents on a pre-established scale, typically a 5-point Likert scale. For this study, the index was determined for each attribute using (1), where  $w$  represents the weight assigned by a respondent (from 1 to 5),  $n1$  to  $n5$  are the numbers of respondents for each score,  $A$  is the maximum score (5), and  $N$  is the total number of respondents. The relevant response data were compiled and processed via this equation to obtain the RII for each cluster. These rankings thus help clearly identify the priority areas perceived by companies in terms of their impact on operational performance.

$$RII = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \tag{1}$$

Table XIV shows the ranking of the "soft" factors and reveals that the "Performance Management System" (SP05) is perceived as the most crucial, with an RII of 81.87%. It is closely followed by the "Continuous Improvement System" (SP03) with an RII of 76.49%, and the "Employee Development System & Continuous Training" (SP02) which ranks third with an RII of 68.21%. These results underscore the importance placed by respondents on managing individual and collective performance, engaging in continuous improvement, and developing staff skills as pillars of OE. This ranking is particularly revealing because it highlights a prioritization that may differ from theoretical expectations, where factors like communication or recognition might be considered more important. The predominance of performance management

systems (SP05) and continuous employee development (SP02) reflects the dynamics of a young and rapidly growing workforce (62% aged between 20 and 30), for whom performance visibility and skill development opportunities are essential levers for engagement and motivation.

Table XV ranks the hard factors. It can be seen that "Problem Solving" (HP04) stands out as the most important factor, showing an RII of 71.04%. "5S" practices (HP01) follow with an RII of 69.71%, and "Standardization" (HP03) with an RII of 66.61% comes next. This hierarchy highlights the strategic value of the ability to effectively identify and solve problems, maintain an organized work environment, and standardize processes to ensure quality and operational efficiency.

TABLE XIV. RANKING OF "SOFT" FACTORS BASED ON RII

"Soft" Factors	Number of Responses	RII (%)	Total Score	Ranking
SP05	587	81.87	2403	1
SP03	587	76.49	2245	2
SP02	587	68.21	2002	3
SP04	587	64.70	1899	4
SP01	587	59.45	1745	5

TABLE XV. RANKING OF "HARD" FACTORS BASED ON RELATIVE IMPORTANCE INDEX

"Hard" Factors	Number of Responses	RII (%)	Total Score	Ranking
HP04	587	71.04	2085	1
HP01	587	69.71	2046	2
HP03	587	66.61	1955	3
HP02	587	56.46	1657	4
HP15	587	48.99	1438	5
HP06	587	48.59	1426	6
HP13	587	48.25	1411	7
HP14	587	48.25	1416	8
HP12	587	48.07	1187	9
HP09	587	47.46	1393	10
HP16	587	46.71	1371	11
HP07	587	46.37	1361	12

G. Model Framework

The conceptual diagram of Figure 1 illustrates the proposed research framework, detailing the relationships between the different categories of variables under study. It highlights a central dependent variable, OE, whose measurement and explanation are the primary objectives of the study. To assess OE, the model incorporates two groups of predictor variables: "Soft Factors" and "Hard Factors," suggesting that these two sets of factors directly influence OE. Furthermore, the framework includes several control variables, such as Company Size, Turnover, Existence Age (Years in Operation), Company Origin, and Ecosystem. These control variables are included to isolate the pure effect of "soft" and "hard" factors on OE, by accounting for organizational characteristics that might also influence the outcome. This visual model provides a clear roadmap for data analysis, specifying the hypothetical relationships to be tested.

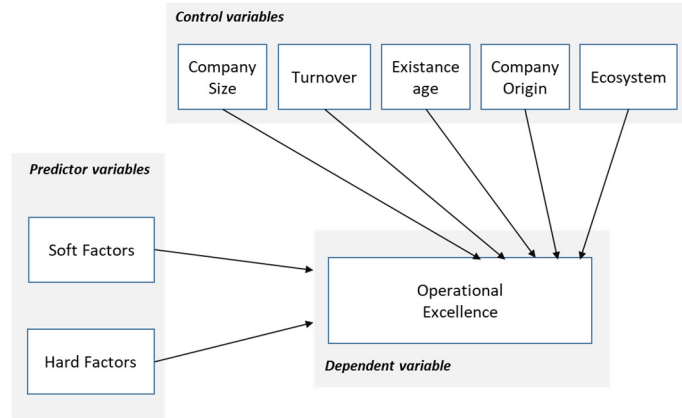


Fig. 1. Model framework.

Table XVI presents the results of hypothesis tests evaluating the impact of "Hard" and "Soft" OE practices on OE itself. The statistical results confirm both formulated hypotheses.

Specifically, for Hypothesis H1 ("Hard Factors Have a Positive and Significant Impact on OE"), the test reveals a t-value of 3.01 with a p-value of 0.003. Since the p-value is less than the common significance threshold (0.05), the hypothesis is supported, indicating that "Hard" practices have a statistically significant impact on OE.

Similarly, for Hypothesis H2 ("Soft Factors Have a Positive and Significant Impact on OE"), the test yields a t-value of 3.06 and a p-value of 0.002. This p-value, also less than 0.05, leads to the hypothesis being supported, thereby demonstrating that "Soft" practices also play a statistically significant role in achieving OE.

In summary, these results underscore the combined importance of both tangible and intangible approaches in promoting OE within organizations.

Beyond the direct impacts, we also conducted an exploratory analysis to investigate potential interaction effects between 'hard' and 'soft' factors on OE. While our initial models did not reveal statistically significant interactions within our dataset, this investigation nevertheless underscores the inherent complexity of OE dynamics. The absence of a statistically significant interaction may indicate that the effects of "hard" factors on performance are not conditionally dependent on the level of "soft" factors, and vice versa. However, it is also plausible that these interactions are more nuanced, follow non-linear patterns, or become apparent only within certain contextual conditions that our current model has yet to fully capture. This finding is crucial as it suggests that a simple multiplicative effect may not be present, but rather that a more complex, synergistic relationship exists. Future research could beneficially employ more advanced methodological approaches (e.g., structural equation models incorporating interaction terms, or mediation/moderation analyses) to deepen this understanding and pinpoint potential synergies or antagonisms between these two categories of factors.

TABLE XVI. RESEARCH HYPOTHESIS TESTING

Hypothesis	Statistical result t/f	p-value	Result
H1	3.01	0.003	Supported
H2	3.06	0.002	Supported

These findings carry substantial relevance within the evolving landscape of the Moroccan automotive industry. The demonstrable influence of both technical (hard) and human (soft) factors on OE directly supports Morocco's strategic objective of solidifying its position as a prominent global automotive center. The confirmed significance of elements like Performance Management Systems and Continuous Improvement practices suggests that the sector's expansion is propelled not solely by investments in infrastructure and technology, but equally by robust process optimization. Concurrently, the emphasis on aspects such as Problem Solving and Employee Engagement underscores the indispensable role of human capital cultivation, collaborative efforts, and an adaptive organizational culture. These are all vital components for sustained competitiveness within a rapidly transforming global value chain. For example, the observed advantages favoring larger, well-established, and foreign-owned enterprises are consistent with Morocco's approach of attracting key international players. These entities typically introduce sophisticated operational methodologies and a culture of high performance, thereby contributing significantly to the enhancement of the domestic automotive ecosystem and its international standing.

### III. LIMITATIONS AND FUTURE WORK

This study, while providing valuable insights into OE in the Moroccan automotive sector, is subject to several limitations that should be acknowledged. Firstly, its cross-sectional design prevents the establishment of causal relationships. The data captures a snapshot in time, meaning we can identify correlations between "hard" and "soft" factors and performance, but we cannot definitively conclude that these factors cause the observed performance levels. To explore causality, future research should adopt a longitudinal approach, tracking changes over time.

Secondly, the generalizability of our findings is limited by the specific context of the study. While our high response rate (93%) ensures representativeness of the Moroccan automotive industry, the results may not be directly applicable to other industries or to the automotive sector in different countries with distinct socio-cultural, economic, and regulatory environments. For example, the specific challenges related to a workforce heavily concentrated in the 20-30 age group may be unique to this context and thus limit the transferability of our recommendations.

Thirdly, this study may be susceptible to Common Method Bias (CMB), as all data were collected through a single self-reported questionnaire. Although rigorous methodological steps were taken to mitigate this issue (e.g., anonymous responses, clear instructions, balanced item wording), the possibility remains that correlations are inflated due to the measurement method rather than the constructs themselves.

Future research could use multiple data sources, such as objective performance metrics or interviews, to address this issue.

Finally, while our model explains a significant portion of the variance (R-squared of 0.441), the remaining 56% points to the influence of other unmeasured factors. This suggests that the pursuit of OE is a complex and multi-faceted phenomenon. Future research could explore additional variables such as the role of organizational structure, leadership styles beyond the scope of this study, strategic orientation, or the level of digital maturity within these companies. Incorporating these elements could lead to a more comprehensive understanding of the factors that drive performance.

### IV. CONCLUSION

This study aimed to evaluate the influence of Operational Excellence (OE) practices on company performance within the Moroccan automotive sector, a context characterized by rapid growth, a young workforce (62% aged 20-30), and a strong presence of multinational corporations (74.8%). The core objective was to understand how both "hard" (technical systems) and "soft" (human dynamics) factors collectively contribute to superior operational outcomes within this industrial landscape. Leveraging a robust quantitative approach, a meticulously developed and validated structured questionnaire was administered to 264 firms in the Moroccan automotive industry, yielding 246 usable responses for reliable statistical analysis. The key findings of this research confirm the significant and synergistic impact of both OE practices. This discovery holds particular importance for the Moroccan automotive sector. It underscores that the industry's impressive growth, which has made Morocco a top player on the continent, is not solely dependent on technological investments but is equally driven by robust process optimization and, crucially, on human capital development and a responsive organizational culture. The confirmed significance of "hard" factors is consistent with the need for strong foundational practices in a developing industrial ecosystem. Concurrently, the critical role of "soft" factors is especially relevant given the sector's young and dynamic workforce, which requires strong leadership, training, and engagement to thrive. The attraction of multinational firms, often bringing these advanced practices, strengthens the local ecosystem and its global standing, further explaining the positive impact of foreign ownership on performance.

These discoveries underscore that the industry's growth is not solely dependent on technological investments, but also on robust process optimization and, crucially, on human capital development and a responsive organizational culture. For Moroccan companies, it is imperative to invest not only in tools and methods ("hard" factors) but also, and most importantly, in training, employee engagement, and fostering a culture of problem-solving and continuous improvement ("soft" factors). The attraction of foreign firms, often bringing these advanced practices, strengthens the local ecosystem and its global standing. These companies often benefit from significant advantages, including access to larger capital, established supply chain networks, cutting-edge technologies, and institutional know-how in quality management and process

efficiency, which allows them to achieve OE more easily compared to local Small and Medium Enterprises (SMEs).

However, implementing OE is not without challenges; it can face organizational resistance to change and require sustained commitment from leadership, as well as significant initial investments. Furthermore, an overly rigid application of its principles can sometimes hinder innovation and creativity, which are essential for adapting to a constantly evolving business environment. It is therefore crucial to balance process efficiency with flexibility and the promotion of a culture of continuous learning. In this context, sustainability and ESG (Environmental, Social, and Governance) performance considerations are not just an addition to be considered; OE is in itself a crucial lever for achieving these objectives. By optimizing resource efficiency and reducing waste, it intrinsically contributes to environmental and social sustainability, a key factor in strengthening the competitiveness and image of the Moroccan automotive industry on the international stage.

The findings of this study have significant practical implications for several stakeholder groups within the Moroccan automotive industry:

- For multinational and large companies: It is recommended to invest in training and advanced technologies to maintain global competitiveness, integrating ESG criteria as a strategic priority.
- For local SMEs: The focus should be on targeted initiatives for cost reduction and quality improvement. Collaboration with industry associations can facilitate access to best practices.
- For policymakers: The role of incentive policies is crucial, particularly financial and fiscal support for investments in sustainable technologies and staff training.
- For industry associations: They can act as catalysts by organizing workshops and facilitating partnerships for the sharing of knowledge and best practices among companies.

An important finding is that while fundamental practices are well understood, advanced tools are implemented with less effectiveness. This gap suggests that the Moroccan automotive sector, despite its rapid growth, has yet to reach a level of maturity where the most sophisticated continuous improvement tools are fully integrated. This may be caused by a lack of investment in specialized training or resistance to change. To remain internationally competitive, it is therefore imperative to bridge this gap by investing in human capital and training on advanced tools.

In terms of future perspectives, qualitative studies could explore implementation challenges and mitigation strategies. Longitudinal studies might offer deeper insights into the long-term sustainability of these initiatives. Comparative analyses across diverse regional automotive contexts would illuminate unique cultural and regulatory influences. Finally, integrating the impact of emerging Industry 4.0 technologies (such as AI and IoT) within this holistic framework represents a compelling

direction for understanding next-generation operational excellence.

#### DATA AVAILABILITY

The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request, adhering to ethical guidelines and data privacy considerations.

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