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Quality system as a mediating variable of the relationship between lean manufacturing and operational performance in the food industry

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Abstract
The failure to implement lean manufacturing (LM) in the food industry was caused by the overlapping application of LM tools. The application of LM in the food industry is experiencing problems in the form of confusion in the placement of QS or Quality Control (QC). This problem is the background of this research. The objective of this study is to compare two methods of the implementation of LM in improving operational performance (OP), namely (1) making quality control (QC) a part of LM practice and (2) making quality control (QC) a part of the quality system (QS). The applied analytical method was the Structural Equation Modelling (SEM) based on Partial Least Square (PLS). The research findings indicated that "making QC a part of QS" can optimally mediate increasing LM against OP. This study's originality is a comparison of the relationship between LM and OP based on the two methods with large sample sizes. The implications of the findings are expected to become recommendations for applying LM in the food industry, especially in terms of placing quality in its implementation.

Keywords:
Lean Manufacturing (LM);
Operational Performance (OP);
Quality Control (QC);
Quality System (QS);

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INTRODUCTION

As the emergence of Lean Manufacturing (LM) for the first time by Krafcik [1], quality is a part of LM practice. Its implementation still places Quality System (QS) as a part of LM practice. If referring to its initial concept, the complete LM concept has proven beneficial for several industries.

However, it is inversely proportional to its application in the processing industry. In the processing industry, QS is forced to appear before LM because of regulations related to food safety. Therefore, applying LM in the food industry has problems in the form of confusion in the placement of QS or Quality Control (QC).

There are two methods in implementing LM in the food industry, namely a. QC/QS is included in the practice of LM and b. QC/QS is separated from LM. These two methods have also become an endless polemic. The inconsistency of research results on LM in previous studies has been a long debate until now. The successful implementation of LM from the two methods can be seen in Table 1 and Table 2.

Table 1. The Quality System as a Separated Part of The LM Concept

No	Ref.	LM Implementation	Result	LM Process
1	[2]	The applicability of lean management methods for food services in order to achieve efficient operations and eliminate food waste, based on a literature review and three case studies from Polan.	System dynamics modeling in simulating the relationship and corresponding impact of various lean tools on various indicators affecting final food waste in food service organizations.	Step by step
2	[3]	The implementation of Lean (JIT) in the production process and storage system to anticipate the relatively short product expiration.	Lean principles can be applied separately with QS in food production for systematic improvement in product quality improvement	Step by step
3	[4]	Integrates two of the most frequently used tools which are lean (i.e., value stream mapping) and green (i.e., life cycle assessment).	There are separate streams of established research on lean and green management in the agri-food sector, yet very few authors have addressed the intersection of these strategic initiatives	Step by step
4	[5]	The total implementation of LM is inhibited by the quality system.	Quality management practices as a critical point for LM implementation	Step by step
5	[6]	The lean system (Waste reduction, 5S, Single Minute Exchange of Dies (SMED), and Overall Equipment Effectiveness (OEE). LM is inhibited by the number of productions lots in large-scale food industries and unpredictable market demand.	Overall Equipment Effectiveness (OEE) as a QS parameter in large-scale production	Step by step
6	[7]	The separate relationship between TQM and LM, LM implementation for manufacturing process with halal certification	The separation of TQM and LM practices is effective in implementing the manufacturing process with halal certification	Step by step
7	[8]	Quality management and halal certification LM is inhibited by the Halal System	Correlation Quality management and halal certification have a positive impact but LM is hampered by the Halal System	Step by step
8	[9]	Quality Assurance such as ISO, BRC, and HACCP for food processing in MSMEs Lean adoption based on a gradual approach	The gradual adoption of Quality Assurance such as ISO, BRC, HACCP is able to facilitate the implementation of LM	Step by step
9	[10]	Systemic Lean Intervention (SLI) A combination between lean tools and QS in poultry feed industries.	The combination of lean tools and QS makes it easier to implement Lean Systemic Interventions (SLI)	Step by step
10	[11]	LM implementation (pull systems, continuous flow, setup time reduction, TPM, statistical process control, and employee) Enhancement of quality-based manufacture.	Improved quality-based manufacturing can speed up the LM process	Simultaneous
11	[12]	Just in Time (JIT), Value Steam Mapping (VSP) and 5S method. 5S does not affect the quality	Not all LM tools are able to improve product quality	Simultaneous
12	[13]	Increase in performance through some variables including TQM, LM, Halal Standard, HACCP HALAL and HACCP do not affect performance.	Gradual implementation of LM and TQM can improve OP	Simultaneous
13	[14]	Green Lean TQM Islamic Process Management Practices in Malaysian food industries Collaboration of TQM, LM, Environmental Management System (EMS) and Islamic Management Practice. Those three did not result in the expected results	The application of TQM and LM simultaneously with other systems does not provide optimal results	Simultaneous

Table 2. The Quality System as a Part of The LM Concept

No	Ref.	LM Implementation	Result	LM Process
1	[15]	TQM is a tool in the LM implementation as an LM tool Quality Filter Mapping to enhance integrity and quality through logistic performance	TQM as an LM tool can improve logistics performance	Simultaneous
2	[16]	The implementation of quality improvement in LM implementation The selection of LM tools (5S, visual control, TPM and SMED)	Choosing the right LM tool can speed up quality improvement	Simultaneous
3	[17]	LM implementation to enhance the quality system LM is reflected in5S	The application of LM in improving QS is effective for the processing industry	Simultaneous

The description above illustrates that the success of LM is because most companies place QC practice into QS (**QS**$_{QC}$), not on LM. However, some prove the successfulness of LM being included in QC Practice (**LM**$_{QC}$). For this reason, this study investigates the application of **LM**$_{QC}$ if it is applied in the food processing industry. In addition, this study also explores the evolutionary process of implementing LM to be accepted in all industrial sectors, especially the food industry.

No studies have tested the two methods simultaneously in a large sample size previously. This study is conducted to find out the effect of the two methods on operational performance (OP) if applied in the Indonesian food industry. Comparing the two methods will provide a real picture of the implementation of LM in the food industry.

MATERIALS AND METHODS

Research Framework

The two methods of implementing LM (**LM**$_{QC}$ and **QS**$_{QC}$) are included in the same research concept. The relationship between the three variables can be seen in Figure 1. There are two relationship paths: Direct relationship (H1, H2, and H3), and Indirect or mediation relationship (H4). The explanation of the four hypotheses is as follows:

Where: **H1**: LM has a positive effect on OP [18, 19, 20, 21, 22]. **H2**: LM has a positive effect on QS [13]. **H3**: QS has a positive effect on OP [23, 24, 25]. This study focuses more on the comparative effect of the three variables, namely LM on OP with QS mediation if applying the **LM**$_{QC}$ and **QS**$_{QC}$ methods.

The hypotheses examined in this study are as follows. **H1**: LM has a direct positive effect on OP; **H2**: LM has a direct positive effect on QS; **H3**: QS has a direct positive effect on OP; **H4**: LM has a positive effect on OP with QS mediation [26][27]. Research variables' indicators emphasize the results of previous studies, as listed in Table 3. QC practice activities include A31 and A32.

This study used three variables, namely the independent variable (LM), the mediating variable (QS) and the dependent variable (OP). LM had six indicators (four if A31 and A32 follow QS), QS had three, and OP had four. All indicators used refer to previous research.

Research Samples

The samples of this study were food companies registered with BPOM RI in 2021, totaling 145 companies spread across Jakarta, Bekasi, Tangerang, Bogor, Depok, and Bandung. One company is represented by one employee with the positions of director, manager, supervisor, and quality assurance/QC staff.

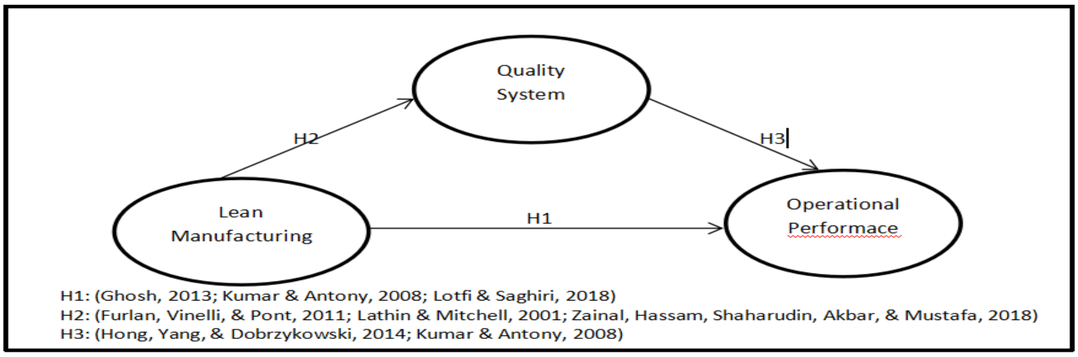

Figure 1. Research Framework

Table 3. Indicators of The Three Research Variables

Variable	Code	Indicator	References
Lean manufacturing	A12	Lay out	[28]
	A13	Pull System	[28]
	A21	TPM	[28]
	A23	Kanban System	[28]
	A31	Statistical Data Technique	[28]
	A32	Visual /Sensory Control System	
Quality System	D42	Quality Assurance	[22]
	D52	TQM	
	D53	Quality Policy	[29]
Operational Performance	Y12	Cost Reject	[28]
	Y13	Sales Growth	
	Y22	Return Product	[28]

Methods

Comparison of the effectiveness of QS as a mediating variable of the relationship between the application of LM ($\mathbf{LM}_{Qc}$ and $\mathbf{QS}_{Qc}$) to the OP, using the Structure Equation Model (SEM) based on the Partial Least Square (PLS) approach with Smart PLS software. Which is divided into two stages: 1) preliminary analysis (validity and reliability of the instrument). 2) Model test to prove the hypothesis formed by looking at the coefficient value (β), T statistic, P value, f^2, R^2, Outer Residual Correlation Model. The full explanation is as follows:

Validity and Reliability

For the validity test, the researcher used a cross-loading value of > 0.6 [30] and the square root of average variance extracted (AVE) of > 0.5. For the reliability test, the researcher referred to the standard Cronbach's alpha value of > 0.6 and the standard composite reliability value of > 0.7 [31]

Model Testing

For the model testing, the researcher applied the Structural Equation Modelling (SEM) based on the Partial Least Square (PLS) approach with Smart PLS software. In this study, the test investigated the effects between variables, obtained the construct cross-validated redundancy, and tested hypotheses.

RESULTS AND DISCUSSION

The results presented in this section cover the obtained outcomes from the instrument validity & reliability tests and the model test with SEM. Before testing the model, it is necessary to test the validity and reliability of the instrument, as shown in Table 4. As seen in Table 4, all parameters have met the standard. In other words, the model test can be carried out using the instrument that has been made.

In Table 5, it can be seen that the activities of using statistical data technique (A31) and visual/sensory control system (A32) have a close correlation with the LM and QS variable indicators in which the Outer Model Residual Correlation values of A31 and A32 are about 0.4 to the indicator in LM and QS. Model testing was carried out twice for the $\mathbf{LM}_{QC}$ and $\mathbf{QS}_{QC}$ methods, respectively. Figure 2 shows the model test using the $\mathbf{LM}_{QC}$ method.

Table 4. The Results of The Instrument Validity & Reliability Tests

Tests	Parameter	Standard	Results
Convergent Validity	Loading factor (outer loading)	> 0.6	0.6 - 0.8
	AVE	> 0.5	0.583 - 0.76
	Communality	> 0.5	0.583 - 0.76
Discriminant Validity	Root Square AVE and correlation of latent variables	Root Square AVE > Discriminant validity	Root Square AVE > Discriminant Validity
	Cross Loading	> 0.6	0.6 - 0.8
Reliability	Cronbach's Alpha	> 0.6	0.660 - 0.748
	Composite Reliability	> 0.7	0.803 - 0.885

Table 5. Outer Model Residual Correlation

	A12	A13	A21	A23	A31	A32	D42	D52	D53	Y12	Y13	Y22	Y41
A12	**1.000**	0.205	-0.252	-0.102	-0.272	-0.116	0.008	-0.208	0.092	-0.039	-0.009	-0.059	0.009
A13	0.205	**1.000**	-0.051	-0.001	-0.246	-0.341	-0.281	-0.143	-0.026	-0.016	-0.038	0.024	0.046
A21	-0.252	-0.051	**1.000**	0.202	0.065	-0.282	-0.396	-0.192	0.139	-0.040	-0.067	-0.132	0.078
A23	-0.102	-0.001	0.202	**1.000**	0.041	-0.144	-0.456	-0.269	0.104	0.045	-0.048	-0.079	-0.026
A31	0.472	0.446	0.465	0.441	**1.000**	0.423	0.400	0.457	0.460	0.416	0.448	0.434	-0.076
A32	0.416	0.391	0.482	0.412	0.423	**1.000**	0.465	0.393	0.436	-0.012	0.128	0.126	0.012
D42	0.008	-0.281	-0.396	-0.456	-0.300	-0.017	**1.000**	0.267	-0.005	0.001	0.055	0.012	0.036
D52	-0.208	-0.143	-0.192	-0.269	-0.357	-0.293	0.267	**1.000**	-0.045	0.040	0.008	0.080	0.071
D53	0.092	-0.026	0.139	0.104	0.060	-0.236	-0.005	-0.045	**1.000**	-0.154	0.219	0.420	0.234
Y12	-0.039	-0.016	-0.040	0.045	0.016	-0.012	0.001	0.040	-0.154	**1.000**	0.144	-0.314	-0.548
Y13	-0.009	-0.038	-0.067	-0.048	0.048	0.128	-0.055	0.008	-0.219	0.144	**1.000**	-0.327	-0.429
Y22	-0.059	0.024	-0.132	-0.079	-0.034	0.126	0.012	0.080	-0.420	-0.314	-0.327	**1.000**	0.024
Y41	0.009	0.046	0.078	-0.026	-0.076	0.012	0.036	-0.071	-0.234	-0.548	-0.429	0.024	**1.000**

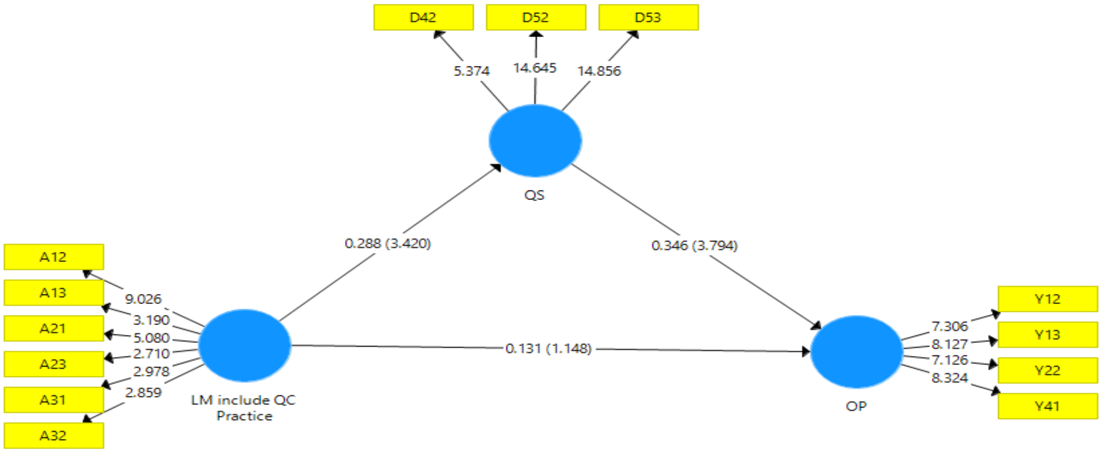

Figure 2. The Model Test with The **LM**QC Method

In Table 6, **LM**QC has not been shown to have a direct positive effect on OP. The condition is contrary if **LM**QC is mediated by QS, which turns out to have a positive effect on OP. The QS variable can be explained by **LM**QC by 28%, while QS and LMQC can explain the OP variable by 53.2%.

In the **QS**QC method, the positive relationship occurs when the QC practice indicators are included in the QS practice and are not part of the LM. Figure 3 shows that the relationship between LM and OP has a negative effect even though the LM variable has a positive effect if the QSQC variable mediates it.

Table 7 helps test hypotheses by considering the coefficient (β) values, t-statistics, and *p*-value. The magnitude of the effect can be seen at the value of f^2. All relationships between variables have a positive effect, except for H1. The coefficient (β) shows negative results. This means that activities in LM (without the QC practice) are not able to increase OP and conversely weaken it. The **QS**QC variable can be explained well by LM by 34%, while QSQC and LM can explain the OP variable by 57.5%.

Table 6. Testing the effect of variables with the **LM**QC method

Hypothesis	Paths	Coefficient (β)	T-statistics > 1.65	*p*-Value < 0.05	f^2	Note
H1	**LMqc - OP**	0.131	1.148	0.056	0.01	(+) not significant
H2	**LMQc - QS**	0.288	3.420	0.009	0.08	(+) significant
H3	**QS- OP**	0.346	3.794	0.000	0.32	(+) significant
H4	**LMQc – QS- OP**	0.227	1.680	0.047	0.10	(+) significant

f^2= 0.02 - 0.15 indicating Weak Effect; f^2= 0.15 - 0.35 indicating Sufficient Effect; f^2 ≥ 0.35 indicating Strong Effect.
R^2: QS. 0.28......OP: 0.42
Goodness of Fit > 0.36

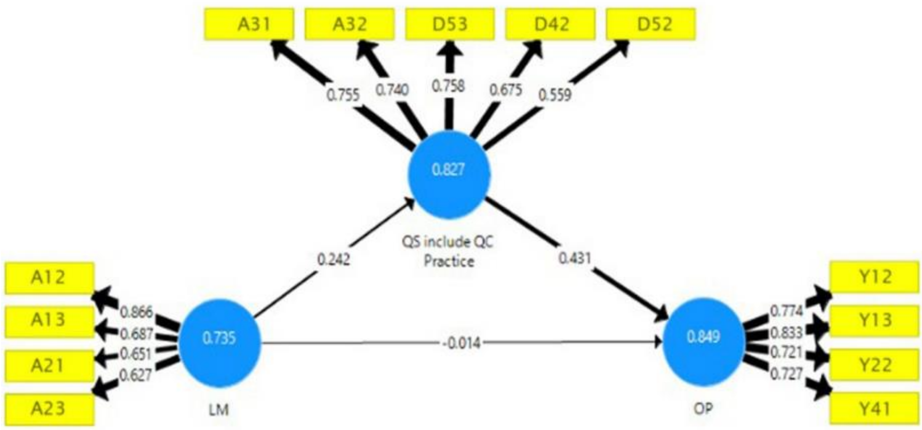

Figure 3. The Model Test with The **QS**QC Method

Table 7. Testing The Effect of Variables with The $\mathbf{QS}_{QC}$ Method

Hypothesis	Paths	Coefficient (β)	T-statistics > 1.65	*p*-Value < 0.05	f^2	Note
H1	**LM - OP**	-0.014	0.918	0.103	0.00	(-) not significant
H2	**LM - QS** $_{Qc}$	0.242	1.651	0.047	0.06	(+) significant
H3	**QS** $_{Qc}$ **- OP**	0.431	4.698	0.000	0.352	(+) significant
H4	**LM– QS** $_{Qc}$ **- OP**	0.243	1.660	0.045	0.13	(+) significant

f^2= 0.02 - 0.15 indicating Weak Effect; f^2= 0.15 - 0.35 indicating Sufficient Effect; f^2 ≥ 0.35 indicating Strong Effect.
R^2: $\mathbf{QS}_{QC}$. 0.34......OP: 0.575
Goodness of Fit > 0.36

Discussion

This study's main objective is to compare the relationship between LM and OP mediated by QS with the implementation of $\mathbf{LM}_{QC}$ and $\mathbf{QS}_{QC}$ methods. Furthermore, the differences in the results of the two methods are as follows.

The $\mathbf{LM}_{QC}$ Method

In the $\mathbf{LM}_{QC}$ method, it can be seen that the QC activities (i.e., the use of statistical data technique (A31) and visual/sensory control system (A32) become activities in LM.

In Figure 4, $\mathbf{LM}_{QC}$ has not been able to increase OP (p>0.05), thereby making it need an intervening variable (QS) to have a positive effect. The implementation of the layout activities, pull system, TPM, and Kanban system went according to what was expected even though the implementation had not gone well. The confusion arises during the implementation of the QC activities. Two activities (A31 and A32) can still not increase their effect on OP. It takes many QC activities to increase its influence. In addition, other QC activities (besides A31 and A32) are included in the QS indicator.

It is difficult for a quality control system to positively impact OP [25] if its implementation coincides with all LM practices. In addition, gradual implementation will have an optimal impact. Moreover, there is confusion if food companies apply the QS and LM concepts simultaneously, namely the overlapping of LM practices which will complicate the LM evaluation process.

In this study, QC became part of the practice of LM as the initial concept of LM, confusing the application of LM through QC in increasing OP. Therefore, QC should have a positive correlation with all OP indicators. This is in line with a study conducted by Dora & Gellynck [9]. If it runs well, it will make it easier for companies to apply the LM concept by strengthening QS as part of food safety.

In this study, the visual/sensory quality control system has not been able to increase OP. This result confirms the findings of Budianto et al. [28] who experienced problems with product quality standards in the form of shape, smell, and taste.

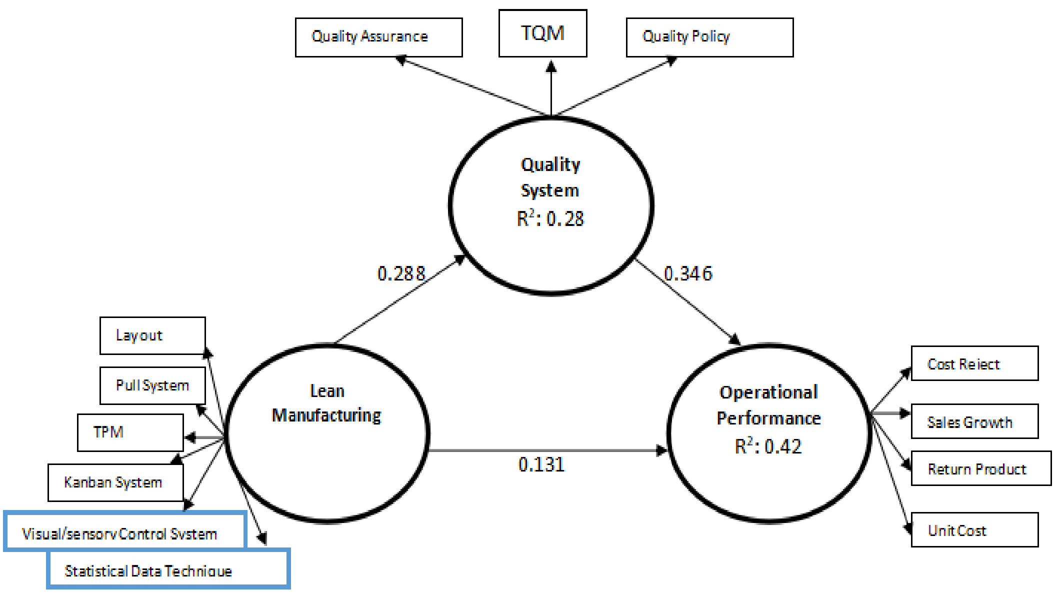

Figure 4. The Effect of Variables with The $\mathbf{LM}_{Q}$ Method

These three standards still rely on the five senses in their test. Therefore, differences in perception will be an obstacle to those standards. The results of this study contradict the findings of previous researchers, such as those mentioned in the following. First, visual control is a quality that positively impacts the implementation of LM [26][32]. Second, the visual control system/sense is an attempt to juxtapose LM with quality, in which quality is a part of the LM concept.

The QS_{QC} Method

In this method, QC activities (i.e., the use of statistical data technique (A31) and visual/sensory control system (A32) are a part of QS. In general, those two activities admittedly are a part of QS. The A31 and A32 activities are examined by realizing product standard references (quality policy) with complete procedures and documentation stages (quality assurance) so that the implementation of TQM may provide optimal results in **QS**$_{QC}$.

Figure 5 shows that LM activities without QC have a negative effect on OP. Furthermore, the relationship between LM and QS variables decreases to 24.2% (28.8% in the **LM**$_{QC}$ method). Moreover, there is an increase in coefficient (β) by 43.1% (34.6% in the **LM**$_{QC}$ method). LM has a negative effect on OP caused by LM activities, such as layout, pull system, TPM, and the Kanban system, which are less than optimal if addressing the OP directly. This can be seen from the outer residual correlation model, in which each of them has not been optimally impacted the OP, especially cost rejects (Y12) and sales growth (Y13), and only has a positive impact on product return (Y22) and unit cost (Y41). Meanwhile, the biggest impact on OP activities (Y12, Y13, Y22, and Y41) is given by the QC activities (A31 and A32).

The **QS**$_{QC}$ method returns QC activities (A31 and A32) to its parent (QS), resulting in collaboration synergy with quality assurance (D42), TQM (D52), and quality policy (D53) which previously had a positive impact on the OP activities (Table 5). The failure of QC activities (A31 and A32) in the **LM**$_{QC}$ method is caused by the lack of support for QC activities, especially the visual/sensory control system (A32) activity. The **QS**$_{QC}$ method helps A32 be more aggressive in finding patterns when collaborating with quality assurance (D42), TQM (D52), and quality policy (D53). This can be seen from the visual test that most food companies initially avoided. Currently, it becomes a unique strategy that has a competitive power.

The visual test is still needed and carried out by several food companies in Indonesia. The visual/sensory control system is used when the test equipment cannot replace the visual test role [30, 33, 34]. The fixed standard is demanded greater in synthetic raw materials, while natural raw materials will have more unfixed standards.

Therefore, it needs to combine consumer behavior that requires healthy eating patterns so that natural raw materials may have their unique attraction even though they have obstacles in determining their organoleptic standards (smell and taste).

The visual/sensory control system that does not positively impact OP (**LM**$_{QC}$) has been successfully converted into the **QS**$_{QC}$ method to be flexible and agile. Both properties can be seen during the standard formulation.

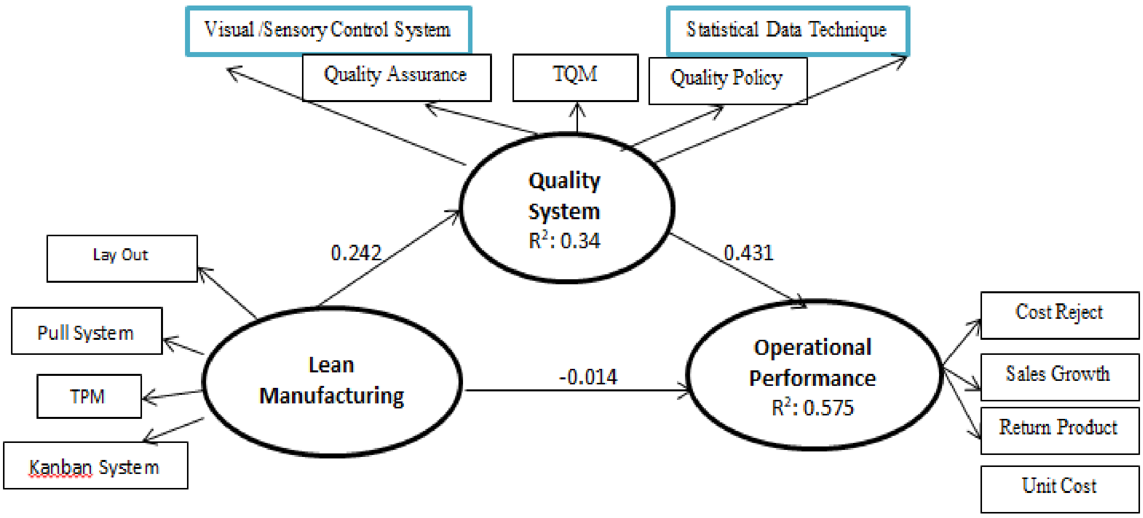

Figure 5. The Effect of Variables with The **QS**$_{QC}$ Method

The visual/sensory control system is correlated with the stability, contaminant level tests (metal and microbiology), material composition, nutritional value tests, and others. The correlation is carried out for making the visual/sensory control system have a fixed standard even though the process is indirect. The presence of a fixed standard in the visual test will trigger food companies to innovate unique products by prioritizing natural raw materials. In addition, the market segmentation that prioritizes natural raw materials is quite extensive, moreover, consumers have realized a healthy lifestyle. Besides, the use of natural raw ingredients will speed up the launching process because the licensing process is faster than using artificial products. In other words, using natural raw materials also opens up opportunities for medicinal products in the form of food identical to herbal drugs and drinks.

By comparing the two methods described above, it is clear that the application of LM to improve OP with the $\mathbf{QS}_{QC}$ method is more effective (*p<0.05*). This finding is in line with previous results [2–5], [7, 9] and contradicts the results using the $\mathbf{LM}_{QC}$ method [15, 16, 17]. Forcing LM with the $\mathbf{LM}_{QC}$ method will result in failure due to the overlapping of LM tools applied simultaneously [33][34]. Therefore, the initial concept of determining QS compared to LM in the food industry must be recognised and understood by applying LM to improve QS so that it has a positive impact on OP. so that all industrial sectors can feel the success of LM.

Managerial implications

The selection of tools in implementing LM will gradually make it easier for a manager to evaluate the effectiveness of LM tools in synergy with QS. The collaboration process of the two systems must be based on real conditions within the company, so that company policies are based on empirical data on sustainable development.

CONCLUSION

The initial concept of establishing LM (quality being a part of the LM practice) has had a tremendous impact on several industries. However, this is inversely proportional if applied in the processing industry (e.g., the food industry). Therefore, LM must be able to evolve to be accepted and applied in all industrial sectors. The evolutionary process is in the form of separating quality from LM tools so that LM activities gradually increase quality, thereby impacting OP.

The separation of quality for becoming an intervening/mediation variable is proven to attract LM to be more flexible, making it impact OP. This separation emphasizes that quality in the food industry appears earlier than in sustainable manufacturing systems (LM). In other words, implementing LM must follow the quality flexibility in increasing OP. This separation also helps LM in the process of evaluating and implementing LM tools that can collaborate with quality (step by step or concurrently)

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