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The impact of using different lean manufacturing tools on waste reduction

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ABSTRACT

Lean and green production was introduced to the western manufacturing industry nearly thirty years ago. The essence of the new business model was to eliminate waste through lean tools according to Taiichi Ohno's eight categories of waste. Many companies became more competitive with waste reduction techniques but some of them faced, and still are facing failures. Such failures are closely related with misapplication of lean and green tools, and its sequential order of implementation. In order to define most powerful lean tools for reduction of certain types of waste, a study was made among lean companies. The concept of a study was to define best lean toolbox for reduction of each category of waste and to determine right sequential order of lean tools implementation. Stepwise multiple regression model revealed that Total Productive Maintenance, Poka-Yoke, Kaizen, 5S, Kanban, Six Big Losses, Heijunka, Takt Time, Andon, OEE, SMED, and KPIs are best waste management techniques. Nevertheless, it has been demonstrated that 5S, Kaizen, Kanban, Poka-Yoke and TPM are highly recommended for start of every lean manufacturing initiative.

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1. Introduction

Many studies have proven that lean and green production can improve operational performance, regardless of the industry where it has been applied [1]. Despite this, many organisations face problems with lean implementation, less than 10 % of organisations which have implemented lean in the U.K. were successful [2]. Studies made in automotive plants in the U.K., U.S.A., and India also showed that the success rate of lean implementation is also low [3]. Each organisation has its individual view of lean methodology, but the success of lean implementation is closely related to the work culture and ongoing efforts to create a value-system approach [4]. Many organisations undergoing lean implementation are looking for a lean-tools implementation 'cookbook'; however, this can provide only short-term improvements [5]. During the process of 'going lean', lean tools are the key to the lean philosophy for organisations because they represent something practical. Philosophy is good for business, but tools work [6]. To achieve long-term benefits from lean production (LP), organisations should focus on building the proper culture, where the culture represents the values, traditions, and ways of thinking that shape the organisation's identity [7]. Recent studies of proper lean implementation have pinpointed that the transition should be made with a project-based approach, with focus on the specific lean tool [8]. If the selection model of lean tools is inaccurate during the lean implementation period, the lean success will be poor or even suspended [9]. All lean activities should have process approach,

where problems have to be solved one after another. Study on Czech companies pointed that usage of standard parts together DFLs (Design for Logistics) can make great results [10].

2. Literature review on lean implementation

The lean concept can be implemented through various methods, but consistent vision is a 'must-have' when an enterprise is moving towards LP [11]. Another vital task for going lean is to create sense of urgency [12] and to create short-term goals to achieve a continuous pace of small improvements [13]. These elements are important for lean implementation, but the most significant element for adoption and sustainability of the lean concept is the organisational culture [14]. It is easier to implement lean in collectivistic cultures than in cultures that promote individualism [15]. The lean concept is a continuous process of seeking perfection that involves everyone in the organisation, including the owners, with a vision of creating a competitive business [16]. The next key element of a successful lean transition is creation of deep understanding among people that the activities they perform have impact on themselves [17]. If an organisation is trying to change its employees' mind-set, the leaders must expend much effort toward achieving the desired behaviour. Lean leadership is the interconnection between the lean toolbox and continuous improvement of the organisation. Leadership is an important element of continuous improvement but leading as an activity is not value-adding, whereas a shop-floor worker is the person who adds value to the product. Shop-floor workers must be encouraged to drive continuous lean improvement [18], so to describe importance of shop floor workers, an often quoted Toyota principle could be used: 'Before we build cars, we build people' [14].

Many authors are proposing a lean roadmap or framework for the transition process of lean implementation to provide an organisation with a general set of guidelines for lean applicability [19]. It has been proven several times that the best lean transitions are provided in the form of roadmaps, where the framework contains well-structured information on principles and practices [8]. In addition, many studies have proven that small and medium-sized enterprises (SMEs) and large companies face different challenges during the lean transition; thus, the lean framework must be adapted to the enterprise size [20]. The next necessity in a successful lean transition is management commitment and leadership [21]. Management must be charismatic, active, and visible on every level and share their enthusiasm for execution of the transition [22]. In lean management, it is preferable that the management know the company very well, and ideally, they should have worked their way up through all organisation levels. This ensures that management has deep knowledge on all business and production activities, while their deep sense for organisational processes gives them an advantage in coaching others [23]. Every company, but also every country can take benefit from this business model. Recent authors have revealed advantages of lean companies in comparison with others towards going Industry 4.0. Lean companies have better organizational integration, standadatization on all levels, complete and precise communication while all activities are essential. This way integration of machines and real time data is minimized to only value-added activities, and Industry 4.0 is meaningful [24].

Lean production can be described and measured as a toolbox full of methods and tools for waste reduction or elimination [25]. On a strategic level, LP can be described as a philosophy; on a tactical level, LP is a set of principles; and on an operational level, LP is a set of practices and tools [26]. Therefore, the biggest challenge for an organisation is to acquire the proper lean tool in time to effectively accomplish its desired goals [27]. People involved in the lean transition must have sound knowledge and an in-depth understanding of lean thinking to achieve effective lean tools and sustain the transformation process [28]. There are over one hundred lean tools that can be implemented, but the most important lean management tools are 5S, Bottleneck Analysis, Continuous Flow, Value Stream Mapping (VSM), Heijunka (Level scheduling), Hoshin Kanri (Policy deployment), Jidoka (Autonomination), Just-In-Time (JIT), Kaizen (Continuous improvement), Kanban (Pull System), Key Performance Indicators (KPIs), Muda (Waste), Overall Equipment Effectiveness (OEE), Plan-Do-Check-Act analysis (PDCA), Poka-Yoke (Error Proofing), Root cause analysis, Single-Minute-Exchange of Dies (SMED), Visual Factory, SMART goals, Standardised Work, Takt Time, Total Productive Maintenance (TPM), Gemba (The real place)

and Six Big Losses, as of March 23, 2017, as Vorne Industries listed on its website. Some researchers suggest implementing all or most lean tools to achieve a successful lean transition [29], but the most frequently used lean principles among large multinational enterprises are Standardised work, Kaizen, Quality programs, Pull System, Flow Orientation, Value Stream, Employee Involvement, Visualisation, Customer Focus, Stability and Robustness, Workplace Management, and JIT. SMEs have a distinctive characteristic compared to large companies, and study made in Serbia has revealed that Standardized Work, 5S, VSM and Kaizen can have significant role in lean implementation [30]. All these principles and tools must be seen as a direction, and not as an end goal [31]. However, the implementation of a different set of lean tools, in conjunction with other relevant factors, will put the organisation in a different state at certain times. Lean was first adopted by automotive industry [32], so it is significant to mention major lean tools that have the most positive impact on automotive organisations. Research on 91 automotive organisations has resulted in awareness that 5S, OEE, the 8-step problem-solving method, Pareto Analysis, Elimination of Waste, Kaizen, Setup Time Reduction, Process Mapping, and VSM are the lean tools that are the most influential in automotive industry environment [33]. All these tools have significant meaning in their respective environments; however, tools must not be copied directly from the literature. Lean practices and tools must be adapted carefully for each organisational framework to achieve a continuous improvement with a strong local impact [34].

3. Materials and methods

3.1 Overview

The guiding concept of this research was to point out major operational features of the lean transition process, with the ultimate goal of addressing the best lean tools for reduction or even elimination of waste according to Taiichi Ohno's 8 types of waste. The research was carried out in Croatia during 2017 and 2018 in the form of a questionnaire, where lean companies were identified through the three criteria presented in subchapter 3.2.

Generally speaking, all interviewed persons were from upper or middle management and closely related to business development. The survey covered nearly 300 companies; however, it should be noted that approximately 230 companies stated that they do not use or have never used lean manufacturing in their management models.

The questionnaire form was divided into three segments, where each segment was designed to reveal a certain aspect of the lean transition:

1) The first segment of questionnaire was in the form of scoreboard, where respondents provided information about their waste according to Taiichi Ohno's 8 types of waste.
2) The second segment of the questionnaire was based on a lean-tools implementation framework, and respondents provided information about the lean tools they had implemented, the lean tools had some positive impact, and the sequential order of lean tools implementation.
3) The third segment of the questionnaire was in the same form as the first segment, as a scoreboard, where respondents provided information about their improvements according to Taiichi Ohno's 8 types of waste. This segment of the questionnaire was designed to provide feedback about the lean implementation success.

3.2 Criteria for selecting the lean companies

Three forms of acquiring data were used for identifying lean companies in Croatia:

- The first form was created at the Green and Lean Production conference 2017 (GALP 2017). This conference was chosen for data collection because this is the largest conference in Croatia that deals with lean manufacturing. This conference was attended by approximately 150 lean practitioners from 40 companies.
- The second method was by contacting the Croatian Chamber of Economy and obtaining a list of all the companies that had attended lean presentations and courses in the last five

years. In this method, approximately 70 companies were contacted, although only 13 companies stated that they use lean manufacturing. These 13 companies completed the questionnaire.

- The last method was based on simply interviewing the best companies in Croatia. The best way to find successful companies in Croatia was to procure a list of the best companies in 2017 from the most-read business journal. Nearly 200 companies were contacted, while 32 replied affirmatively, saying that they use lean manufacturing.

Altogether, approximately 300 companies were covered by this research, where 63 companies were pinpointed as companies that used or still use lean production tools in their everyday activities.

3.3 Used software tools

This study was made in Statistical Package for the Social Sciences (SPSS) on a sample of 63 lean organisations, wherein a stepwise multiple linear regression model (SMLR) was carried out to find the most significant lean tools for boosting the reduction of different types of waste. As Taiichi Ohno categorised waste into eight types, it was logical to focus the survey on the quest for the most significant lean toolbox for each waste type. The input variables were the lean tools usage and improvement in the reduction level of the observed waste type. Specifically, the dependent variable (improvement level of waste reduction for the observed waste type) was measured on a scale from 0 to 3, where 0 stood for 'no improvement', 1 stood for 'small improvement', 2 stood for 'medium improvement', and 3 stood for 'huge improvement'. On the other hand, the independent variable (lean tools usage) was qualitative, where 0 stood for 'we did not use this lean tool' and 1 stood for 'we used this lean tool'. This statistical approach has resulted in clear findings, and the most significant lean tools for waste reduction forecast were determined.

4. Results and discussion

Generally speaking, the concept of lean manufacturing appeared in Croatia several years ago, but many companies still have not had enough courage to implement this concept and culture in their core business activities. Almost 300 companies and 25 lean tools were included in this survey, and 12 lean tools were identified as the best for boosting waste reduction.

4.1 Waste (losses) before going Lean

Lean is the constant search for perfection, where people make incremental daily improvements by eliminating waste. Therefore, it is important to see where the organisation creates small, medium, and large losses before the lean concept is implemented. If the organisation does not know its type and scale of waste, it is possible that incorrect lean tools will be launched to reduce or solve waste. When we talk about the scale of waste in a Croatian organisation, it is clear from Table 1 that these organisations generally have medium or small losses.

Table 1 Survey responses regard waste (losses) before lean

Rank	Type of Waste (Losses)	Subtype of Waste	0	1	2	3
7	Surplus production	Producing products that can't be launched on the market	43%	37%	19%	2%
		Conducting unnecessary operations	2%	56%	33%	10%
		Excess administration	8%	35%	37%	21%
		Poor market demand forecasting	19%	46%	30%	5%
		Production 'just in case'	32%	30%	27%	11%
4	Excess transport	Unnecessary circulation of material between operations	16%	35%	40%	10%
		Ineffective data transfer	3%	30%	52%	14%
		Unsuccessful communication: unreliability and data loss	8%	41%	37%	14%

Table 1 (continuation)

5	Waiting	Latency between operations	5%	41%	37%	17%
		Poor production and processes planning	8%	32%	44%	16%
		Waiting for approval or signature	25%	44%	16%	14%
		Untimely supplier delivery	11%	33%	38%	17%
8	Excess processing	Unreliable or faulty technological equipment	37%	38%	21%	5%
		Bad product design requiring too many processing	35%	27%	32%	6%
3	Redundant stock	Huge inventory on hand 'frozen capital'	17%	27%	37%	19%
		Huge quantities of redundant data in the archives	8%	35%	38%	19%
6	Unnecessary movements	Bad machinery arrangement resulting in movement	22%	44%	21%	13%
		Workers wandering in order to obtain information	13%	49%	27%	11%
		Poor workplace ergonomics	14%	48%	24%	14%
2	Fallout (reject)	Interruption of production flow for poor information	14%	33%	41%	11%
		Time required for fault correction	10%	27%	37%	27%
1	Insufficient use of employee potential	Insufficient use of employee potential	5%	41%	32%	22%
		Poor detection of capable employees	5%	46%	33%	16%
		Insufficient inclusion of workers in the improvements	2%	38%	40%	21%
		Note: scale of waste defined as: 0 = no waste; 1 = small waste; 2 = medium waste; 3 = huge waste				

4.2 Most frequently used lean tools and sequential order of implementation

The lean concept is a philosophy, lifestyle, and culture, but the development of such a lifestyle and culture must be supported by tangible practices, which brings us back to the significance of lean tools. In recent years, there has been a lack of studies made on the sequential order of implementation of lean tools. Enterprises crave a lean implementation cookbook, but nearly all authors have given up on this topic. It is clear that each company has its individual starting point and financial strength before going lean, but some lean tools should have an advantage in implementation over others. Therefore, we can see from Table 2 and Fig. 1 that 5S and Kaizen are the lean tools most used at the beginning of the lean transition. These lean tools are not state-of-the-art tools from the lean concept view, but these tools effect fast and visible improvements in the shop-floor environment. Study made on 49 Polish enterprises revealed that most frequently used tools are 5S, 5xWhy, SMED, Team Work, Standardized Work, Root cause analysis and TPM [35]. All these tools are also in narrow focus of Croatian companies but they tend to use more Standardized Work, Kaizen, 5S, KPIs and VSM. However, Polish companies have ranked waiting, unnecessary movements, fallouts and redundant stock as major waste. On the other hand, Croatian companies have most challenges with reduction of insufficient use of employee potential, fallouts, redundant stock and excess transport. In other settings, such as Lithuania, study among 41 enterprises revealed that most used lean tools are employee training, quality control line in work process, standardized work, gemba, 5S, lean dashboards and PDCA.

Generally speaking, the tools like 5S, Kaizen, VSM, Kanban, Standardised Work, SMART Goals, Muda, and Gemba were the first choice for eliminating waste in Croatian companies. It should be pointed that 5S, Kaizen and Mieruka (Visual Management) are also backbone of most lean initiatives in Vietnam. But then also, Vietnam study revealed that these tools can be more powerful if people have deep understanding on performed tasks. More precisely, if people see benefit in activities, performance will be better, consequently resulting better effectiveness [17].

After the implementation of these tools, the Croatian companies have focused on the implementation of tools like Poka-Yoke, Andon, Continuous Flow, Jidoka JIT, KPIs, OEE, SMED, etc. These tools are more sophisticated than the first one, because they are more complex and require a deep understanding of lean. It is also notable that these tools require more financial resources in implementation than 5S, Kaizen, VSM, etc. In the last phase of lean transition at the Croatian companies, tools like Heijunka and TPM played a significant role.

Table 2 Lean tools implementation framework according to survey participants

Lean practice	1	2	3	4	5	6	7	8	9	10	11	12
5S	49%	22%	19%	8%	0%	3%	0%	0%	0%	0%	0%	0%
Andon	0%	13%	25%	25%	13%	13%	0%	0%	0%	0%	13%	0%
Bottleneck Analysis	7%	34%	14%	14%	24%	7%	0%	0%	0%	0%	0%	0%
Continuous Flow	5%	25%	0%	15%	15%	15%	5%	5%	5%	5%	5%	0%
VSM	23%	27%	27%	3%	7%	3%	7%	0%	3%	0%	0%	0%
Heijunka	0%	0%	17%	0%	33%	17%	0%	0%	33%	0%	0%	0%
Hoshin Kanri	15%	5%	15%	15%	25%	0%	10%	10%	0%	0%	0%	0%
Jidoka	11%	33%	11%	11%	17%	0%	6%	6%	0%	0%	0%	0%
JIT	9%	0%	17%	22%	4%	4%	17%	4%	9%	4%	4%	4%
Kaizen	41%	24%	11%	19%	0%	0%	3%	0%	0%	3%	0%	0%
Kanban	27%	7%	20%	0%	13%	13%	7%	7%	0%	0%	7%	0%
KPIs	14%	20%	26%	11%	6%	9%	3%	3%	3%	3%	0%	3%
Muda	24%	33%	14%	10%	0%	5%	0%	5%	0%	5%	0%	0%
OEE	8%	15%	31%	0%	8%	15%	8%	0%	8%	0%	0%	0%
PDCA	8%	25%	17%	25%	17%	0%	0%	8%	0%	0%	0%	0%
Poka-Yoke	0%	17%	25%	17%	8%	8%	0%	0%	8%	8%	0%	8%
Root Cause Analysis	16%	0%	11%	16%	16%	16%	11%	5%	0%	0%	11%	0%
SMED	0%	5%	19%	19%	19%	10%	5%	10%	0%	0%	0%	10%
Visual Factory	4%	16%	28%	4%	20%	20%	4%	0%	0%	0%	0%	4%
SMART Goals	25%	11%	18%	14%	18%	11%	4%	0%	0%	0%	0%	0%
Standardized Work	23%	21%	8%	15%	10%	5%	8%	5%	0%	0%	3%	0%
Takt Time	14%	7%	0%	29%	0%	7%	14%	7%	0%	7%	0%	0%
TPM	0%	0%	0%	24%	14%	14%	24%	14%	5%	0%	0%	0%
Gemba	19%	19%	25%	6%	13%	19%	0%	0%	0%	0%	0%	0%
Six Big Losses	0%	20%	0%	20%	0%	20%	20%	0%	20%	0%	0%	0%

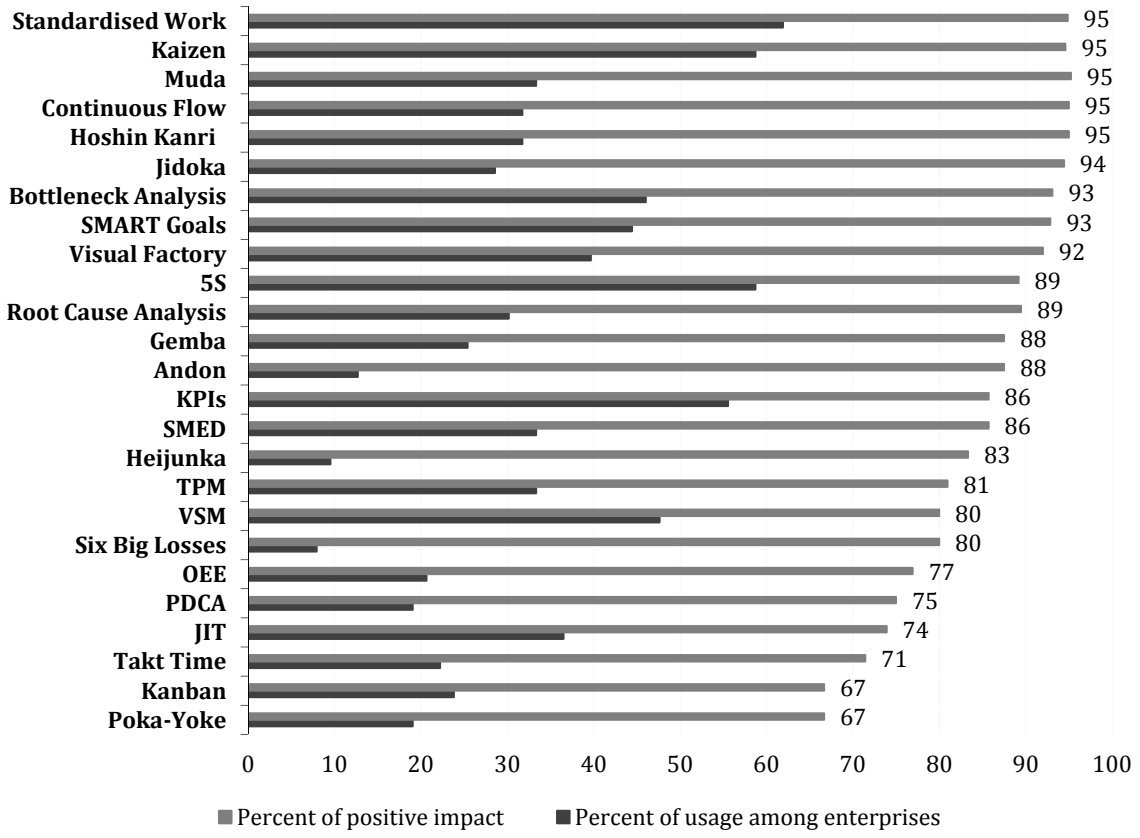

Fig. 1 Lean tools impact according to survey participants

Table 3 Survey responses regarding waste (losses) reduction after lean implementation

Rank	Type of Waste (Losses)	Subtype of waste-reduction improvement	0	1	2	3
6	Surplus production	Producing products that can be placed on the market	40%	48%	10%	3%
		Better operations performance	16%	57%	19%	8%
		Reducing administration	19%	52%	21%	8%
		Better market demand forecasting	29%	48%	17%	6%
		Production with smaller stock	22%	51%	21%	6%
3	Excess transport	Better circulation of material between operations	22%	29%	41%	8%
		Better data transfer	6%	46%	37%	11%
		Better communication: data reliability	6%	44%	38%	11%
4	Waiting	Reducing latency between operations	11%	48%	27%	14%
		Better production and processes planning	8%	43%	32%	17%
		Reducing waiting time for approval or signature	40%	35%	19%	6%
		Better and faster supplier delivery	44%	37%	13%	6%
8	Excess processing	Reliability or better choice of technological equipment	49%	38%	10%	3%
		Better product design not requiring a lot of processing	54%	29%	11%	6%
7	Redundant stock	Reducing inventory on hand 'frozen capital'	33%	46%	11%	10%
		Reducing quantity of redundant data in the archives	25%	54%	14%	6%
5	Unnecessary movements	Machinery arrangement resulting in less movement	38%	38%	19%	5%
		Shorter wandering to obtain information	17%	51%	25%	6%
		Better workplace ergonomics	30%	37%	30%	3%
2	Fallout (reject)	Improvement of the production flow	13%	40%	35%	13%
		Reducing time for fault correction	11%	38%	33%	17%
1	Insufficient use of employee potential	Better use of employee potential	10%	43%	37%	11%
		Better detection of capable employees	6%	48%	33%	13%
		Inclusion of workers in the improvement processes	6%	38%	33%	22%
		Note: scale of improvement defined as: 0 = no improvement; 1 = small improvement; 2 = medium improvement; 3 = huge improvement				

Many companies in Croatia mentioned waste elimination as a trigger for going lean, precisely 67 %. Other triggers mentioned by more than 50 % of participants were increase of efficiency (89 %), profitability (70 %), productivity (67 %) and reduction of manufacturing costs (65 %). Just as a comparison, Polish organizations seek to increase company's operation (81 %) and be more competitive (50 %) through lean management [35]. Again, Lithuanian companies are more oriented on increase of efficiency, problem solving, housekeeping level and overall improvement of organization [36]. The biggest improvements in waste elimination of Croatian companies were achieved in terms of the use of employee potential, fallouts, transportation, and waiting (see Table 3). When we examine Table 1 to determine the largest waste in Croatian companies according to the survey responses, we can see that the insufficient use of employee potential and fallouts are in first and second place. Therefore, many Croatian companies have detected their weakest spots and tried to solve them through the lean concept correctly. On the other hand, redundant stocks and excess transportation were detected by the Croatian companies as the third and fourth most significant waste through survey responses, but waste-reduction progress was not as high as it should be. Excess transportation is in fourth place, and redundant stock is in seventh place of waste-reduction progress. Therefore, we can conclude that only the appropriate lean toolbox can reduce the targeted waste type.

4.3 Most significant lean tools for waste reduction or elimination

The backbone of this research was to find statistically significant lean tools for the reduction of different types of waste. As was said earlier, SMLR was executed on a sample of 63 organisations to address among 25 basic lean tools only one with statistically significant positive impact on waste reduction. Eight SMLR analyses were carried out in SPSS to analyse the relationship between single dependent variable (waste-reduction improvement level on the observed waste type) with twenty-five independent variables (lean tools usage). The goal was to find a set of independent variables that significantly influence the dependent variable. More simply, the goal

was to find, for each waste type, a set of statistically significant variables (lean tools) in the data set, resulting in the best models to increase the predicted waste-reduction improvement level. Such SMLR models could direct lean beginners in right direction during lean implementation and point statistically significant positive lean tools for certain waste types.

Dependent variable for each type of waste was precisely defined through two or more quantifiable measures (subtype of waste-reduction improvement), see Table 3. Survey respondents had to evaluate their subtype of waste-reduction improvement on a scale from 0 to 3 and those answers were summarised into one number from 0 to 3 that was presenting waste-reduction improvement level on the observed waste type. On the other hand, independent variables were defined through the survey respondent used or the implemented lean tools. Each organisation used different lean tools, therefore it was necessary to examine if there is any connection between used or implemented lean tools and waste-reduction improvement level of observed waste type.

The first step for building SMLR models was to check normality, linearity, homoscedasticity, and multicollinearity of data. All assumptions for building SMLR models were checked before running the models. Statistical analyses carried out in SPPS showed us that each type of waste has its best SMLR model for prediction of waste-reduction improvement level (see Table 4). These models are pinpointing statistically significant positive independent variables (lean tools) for prediction of waste-reduction improvement level. In layman's terms, the lean tools in Table 4 are good for implementation in terms of waste reduction, but each type of waste should be reduced with unique set of lean tools presented in the mentioned table.

Furthermore, we can divide the statistically significant lean tools into two groups. The first lean tools group comprises lean tools that statistically significantly reduce several waste types. These tools are TPM, Poka-Yoke, Kaizen, 5S, and Kanban (see Table 5). The second lean tools group comprises lean tools that are statistically significantly reducing only one type of waste. These tools are Six Big Losses, Poka-Yoke, Heijunka, Takt Time, Andon, OEE, SMED, and KPIs (see Table 5).

Summarizing findings presented in Tables 2, 4 and 5 we can say that each lean implementation should be launched and supported by 5S, Kaizen, Kanban, Poka-Yoke and TPM since these waste management techniques reduce several types of waste. In doing so, 5S and Kaizen should be implemented first, Kanban and Poka-Yoke immediately after, while TPM as most powerful waste management technique should be implemented last and with great care. This way, company will achieve quicker higher level of lean maturity whereas progress will be visible on every corner.

Table 4 Best SMLR lean toolbox models for prediction of dependent variable

	Surplus production	Excess transport	Waiting	Excess processing	Redundant stock	Unnecessary movements	Fallout (reject)	Insufficient use of employee potential
R	0.628	0.681	0.742	0.546	0.59	0.582	0.585	0.521
R^2	0.394	0.464	0.55	0.298	0.348	0.339	0.342	0.271
p	0	0	0	0	0	0	0	0
	TPM	**Poka-Yoke**	**Takt Time**	**Poka-Yoke**	**OEE**	**SMED**	**Poka-Yoke**	**TPM**
B (β)	0.697 (0.564)	0.740 (0.410)	0.712 (0.435)	0.653 (0.356)	0.572 (0.352)	0.521 (0.353)	0.932 (0.470)	0.711 (0.441)
	Six Big Losses	**5S**	**Andon**	**TPM**	**Kanban**	**Kaizen**	**Kaizen**	**Kaizen**
B (β)	0.546 (0.254)	0.557 (0.387)	0.638 (0.312)	0.410 (0.269)	0.545 (0.353)	0.392 (0.277)	0.516 (0.326)	0.359 (0.232)
		Heijunka	**5S**		**TPM**	**KPIs**		
B (β)		0.599 (0.248)	0.394 (0.285)		0.446 (0.320)	0.329 (0.235)		
		Kanban	**TPM**					
B (β)		0.350 (0.210)	0.368 (0.255)					

Table 5 Most significant lean tools for waste reduction

Lean tool	Sum of waste types this tool statistically significantly reduces	Usage of this tool will average make progress in waste reduction on scale from 0 to 3
TPM	5	0.526
Poka-Yoke	3	0.775
Kaizen	3	0.422
5S	2	0.475
Kanban	2	0.447
Six Big Losses	1	0.546
Heijunka	1	0.599
Takt Time	1	0.712
Andon	1	0.638
OEE	1	0.572
SMED	1	0.521
KPIs	1	0.329

On the other hand, if organization has goal to reduce one specific type of waste, then statistically significant waste management techniques presented in Table 4 should be applied. For example, if an organisation has problems with redundant stocks, it should use OEE, Kanban, and TPM to ensure that waste reduction will be done in a best possible way. The multiple-correlation coefficient (R) for the redundant-stocks lean toolbox is 0.590, which means that we have a good level of prediction of the dependent variable. The coefficient of determination (R^2) is 0.348, which means that our independent variables explain 34.8 % of the variability of our dependent variable. Table 4 also shows that all independent variables statistically significantly predict the dependent variable, $p < 0.05$ (i.e., the regression model is a good fit of the data). Finally, we can see from the unstandardized coefficients (B) for the redundant-stocks lean toolbox that the use of OEE will improve the reduction of redundant stocks by 0.572 points, the use of Kanban will provide another 0.545 points of improvement, and use of TPM will provide another 0.446 points of improvement. This result shows us that OEE is best predictor of the dependent variable (improvement level of waste reduction on the redundant stocks). Specifically, if we implement OEE in our organisation, we will improve the waste reduction of redundant stock of 0.572 point on a scale from 0 to 3.

A stepwise multiple regression model has shown us that organisations must use the proper lean toolbox for each type of waste. The desired outcome will be achieved with less effort and within a shorter period. This approach is an optimal path, and those who use this logic are saying, 'We prefer to use a scalpel rather than a sledgehammer'.

5. Discussion

There are many factors for lean implementation success. These factors are primarily related to active leading by management, employee education, communication, employee involvement in improvement processes, etc. No matter how well management leads the lean implementation, sooner or later, the lean toolbox will appear, and many questions will be raised. Among many authors, the lean framework is in the top ten critical success factors for lean success. There is no lean concept without lean practices. Lean without tools is just a philosophy. However, lean tools without a value-adding culture are unnecessary.

The Croatian industry missed its chance to be the pioneer of lean in Europe many years ago, but it has a chance now to become more competitive for the upcoming Industry 4.0. and to reduce negative environmental impacts by applying this concept. This survey documented that companies tend to make lean transitions in no more than nine steps, where each step produces a wish to implement one or more lean tools. Some lean tools or practices are used more frequently than others, but their significance cannot be determined only by their occurrence ratio. Lean-tools impact feedback, determined by an SMLR model, must be the measure of their greatness. The presented statistical model has shown us that TPM, Poka-Yoke, Kaizen, 5S, Kanban, Six Big Losses, Heijunka, Takt Time, Andon, OEE, SMED, and KPIs are statistically significant lean tools for waste reduction or even elimination.

Lean was created in a manufacturing environment, and its significance is commonly related to operative and strategic mind-set changes. This survey documented that lean is still the most frequently used method for the operative and strategic restructuring process. Lean tools are not a state-of-the-art product of the lean concept; they are simply visible practices that introduce a desired cultural and mind-set change among all people. A value-adding culture is a final product of lean, whereas a consistent search for perfection must be its basic principle.

Lean is one of many concepts for business improvement; however, successful lean implementation is characteristic of many market leaders. Organisational changes are a necessity on today's market. If market leaders are willing to make deep changes, then there is no excuse for others to not make the necessary changes. Many organisations wanted to adopt lean throughout the years, but lack of knowledge, loss of enthusiasm, and bad decisions led to poor change. Leaders and management are setting the direction of the change by their principles and practices. Lean tools are not just boring procedures, they are setting a framework for future changes. Lean can be simple, pragmatic, and comprehensive for all users only through lean tools. They represent organisational directions and aims.

6. Conclusion

This paper documented the most frequent and most significant basic lean tools for waste elimination among lean practitioners. The documented lean implementation framework enabled us to examine the occurrence of lean tools in all lean implementation stages, where the key lean tools were pinpointed. The results can help organisations see the lean experts' way of thinking. Every organisation should investigate the best practices in their industry for lean implementation. The lean practices identified in this survey are not unique lean implementation paths. Each company should redesign and adapt the lean framework for its needs.

In brief, the management must have a deep understanding of organisation waste and sound knowledge of the lean toolbox to make lean implementation more successful. It is wise to use lean tools that reduce several types of waste as the first steps of lean implementation because they have a statistically significant positive impact on waste reduction. Each lean tool has its own waste-reduction impact. Some tools are more reliable for waste reduction, and others for other tasks. Generally speaking, management should know its priorities before going lean. Going lean is a never-ending process, and tools and practices have a huge impact on lean transformation and creation of smart factories.

This study has some limitations. The lean practitioners interviewed through this survey were involved in lean implementation, but they had an individual view on waste before and after the lean concept. Second, the lean implementation is a long process in which many lean tools are implemented. The presented study investigated 25 basic lean tools; however, the interviewed lean practitioners might have implemented other lean tools during their implementation. Third, some interviewed organisations have a higher lean maturity level and have been using the lean concept much longer than others. Therefore, they have better progress in terms of waste elimination. In general, these results are based on the subjective vision of lean practitioners.

Lean implementation has many critical factors for success. This study has proven that lean tools are involved in every lean implementation. In addition to lean tools, there are many other factors that influence the success, duration, and sustainability of the lean concept. Further investigations should focus more on how managers conduct lean-tools implementation in various industries and other countries.

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