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RESEARCH OF ERP SYSTEM INTEGRATION INTO LEAN MANUFACTURING

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Abstract. Nowadays, the highly competitive market makes industrial companies search for new decisions to improve their competitive advantages. It can be lowering product cost, manufacturing and delivering faster than competitors or being flexible when producing different quantities of different products for different customers. Most popular instruments that help companies to reach previously mentioned competitive advantages are implementing Lean Manufacturing strategies or ERP systems into their production systems. The way of using these systems might become the main indicator of companies' success in the future. This research aims to create a guideline for integrating ERP system into Lean Manufacturing system. It focuses on the manufacturing companies that are already using such a system and can share their good and bad experiences. To reach this aim, the scientific literature is being analyzed by retrieving the CSFs for such an integration process. Using these CSFs, the relation between them and the positive outcomes of the integration process is established and tested using an online survey. The results of the survey are processed using empirical methods. Moreover, the research methodology for evaluating the ERP system integration into Lean Manufacturing level is established and tested in three case analyses.

Keywords: Lean-based ERP system, ERP integration into LM, ERP and Lean integration CSF, Lithuanian industry.

Introduction

Every company in the industrial sector faces similar difficulties when competing with others. It is meeting delivery times, lowering price and meeting required quality. Those difficulties relate to companies' internal indicators and features of the production system. It can be production costs, production throughput, quality system effectiveness, amount of inventory, amount if WIP, etc. Couple of the ways to improve these indicators and features are implementing Lean Manufacturing principles or the ERP system. Although there are some risks, considering the implementation of those instruments, that can cause a company many troubles.

Lean Manufacturing is a long-term commitment that requires a lot of managerial effort to implement and maintain. Furthermore, there is a risk that the implemented system will not reach the intended objectives. On the other side, ERP implementation also requires the discipline of managing people and all other employees in the company. It is also a long-term commitment that could even not reach intended goals. The implementation of both of these instruments costs a lot of money, so the consequences of failure can be financially painful.

Although Lean Manufacturing and ERP system might improve production system working separately, the author of this research believes that the most effective way is to integrate the ERP system into Lean Manufacturing system. Risks of implementing that kind of a system are not different from the ones of implementing systems separately. Therefore, there is a need for fundamental guidelines that could help to lead companies to successful implementation not concerning about complexity of the system or price of a mistake. This project fulfils this need by suggesting the timeline of implementation and CSFs that are most effective when integrating the ERP system into Lean Manufacturing.

1. Background on ERP system implementation into Lean Manufacturing

The literature in the form of scientific researches and papers, books and electronic articles were analyzed to serve as a background for this research. Target topics for this

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analysis were CSFs of Lean implementation, CSFs of ERP implementation and ERP integration into Lean Manufacturing.

CSFs of Lean Manufacturing system implementation process is described in various sources of literature. Most popular CSF is internal Lean experience (Elkhairi et al., 2019). Other important CSFs that are rated in the order of decreasing number of appearance in the analyzed literature are organizational culture (Mohammad & Oduoza, 2019), financial capabilities (Sreedharan et al., 2018), training and education (Blijleven et al., 2019), leadership and management (Hu et al., 2015), communication (Alkhoraif et al., 2019), employee involvement and participation (Dora et al., 2013) and top management support and participation (Elkhairi et al., 2019). The most important CSFs are related to organizational culture and quality of companies' management system. It is because the implementation of Lean Manufacturing is the process of change.

CSFs of ERP system implementation process is also described in various sources of literature. Most popular CSFs are user training and top management support and participation (AboAbdo et al., 2019). Other important CSFs that are rated in the order of decreasing number of appearance in the analyzed literature are company-wide communication (Ozorhon & Cinar, 2015), change management (Agaoglu et al., 2015), project management (Dezdar & Suleiman, 2009), user involvement (Bansal & Agarwal, 2015), clear goals and objectives (Žabjek et al., 2009) and project champion (Reitsma & Hilletofth, 2018). The same regularity of CSFs can be seen here too: the most important CSFs are related to organizational culture and quality of companies' management system.

Furthermore, CSFs for Lean Manufacturing implementation, ERP systems implementation common CSFs of both types of systems were presented. Most important research, from ones analyzed, for this project is (Alsakari et al., 2014) paper about common CSFs for both systems. Those CSFs are compared with CSFs, analyzed for separate systems.

Finally, Literature analysis provided a wide list of ways how ERP can be integrated. For example, (Perico et al., 2019) stated information what functionalities of ERP system can help overcome Lean Manufacturing shortcomings. Although, it might be noticed that not all challenges can be overcome only by using expensive MES system, but it gives a list of functionalities that can be divided into tools for real-time data collection and analysis and production planning and control. Furthermore, (Halgeri et al., 2011) described the main toolsets of ERP systems that can be used in Lean production. This list is mostly concentrated about controlling production on the shop floor and maintaining JIT in it. It consists of such tools as demand smoothing, production smoothing, kanban planning and JIT tools. Also, there is one tool for value stream mapping and value stream analysis. Third author, (Erkayman, 2019) delivers the deep look into how the ERP system can transit the JIT system into the company. He emphasizes on the following production in real-time, following results of delivery and prioritizing orders according to due dates. Also, (Powell et al., 2013) offer a capability maturity model that evaluates the maturity of ERP system integration into Lean Manufacturing following directions of integration: e-kanban procurement, e-heijunka procurement, pull systems feedback to ERP system and vice-versa.

Findings of this scientific literature analysis are used as a background for this research.

2. Research methodology

A method that is chosen for the research is a survey based on a survey that consists of two parts. The objective of the first part of the survey is to evaluate the level of ERP integration into Lean production and how it is used for that purpose. The second part is for finding the effectiveness of CFSs and their relation to positive outcomes if the integration. The survey is designed in the manner that it is not necessary to have the answers of both parts from the one company. A flow chart, representing a methodology of the research can be seen in the Figure 1.

The first section of the first part of the survey is prepared by the author according to the analyzed capability maturity model (CMM) (Powell et al., 2013). The new structure of the questionnaire is established. Three integration levels will be distinguished to simplify the CMM model for Lithuanian industry. Five directions of integration, that were revealed during the analysis of the literature will be analyzed.

Another section of this part of the survey aims to find out the best practice of ERP system integration into Lean Manufacturing. It aims to find out:

1. Structure of the ERP system.
2. Obstacles emerging during the integration process.
3. Overcoming of the emerged obstacles.
4. The most effective way to integrate.

The objective of the second part of the survey is to find the data for correlation analysis between CSF of ERP implementation into Lean Manufacturing process and its'

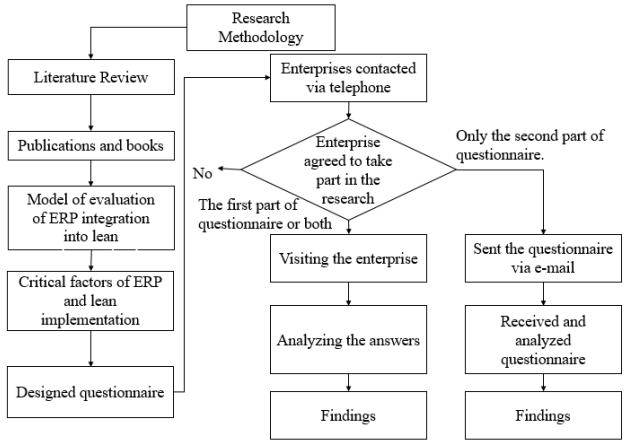

Figure 1. Structure of the research methodology (source: prepared by the author)

positive outcomes. The purpose of questions is to reveal the most important CSF implementation process and the most common positive outcomes of it according to companies that are surveyed. The questions are issued according to the analyzed researches.

Questions are split into two blocks. Each of the blocks has 10 questions to disclose its' topic. Questions are formed in the way that answer will numerically evaluate the appearance of the fact that is stated in the question. It will be done by asking the respondents to evaluate the answer from 1 to 10. It will provide quantitative data for further analysis.

3. Analysis of empirical research (the first part of the survey)

Results of the research are presented according to the methodology of each part of the survey. The first part results are given in written form by giving a basic knowledge about the company and its' manufacturing system, products, ERP system that is being used and explaining the answers of all companies that were involved. Three companies participated in this part of the survey. Under the obligation of anonymity, their names are not mentioned. Instead of that, they are called company A, company B and company C.

Company A is an SME company of Lithuanian industry. It has 246(2020-03-10) employees and 30–50 kk euros in sales revenue. The company specializes in modifications of already existing products. Each product is different and has a lot of components and different processes that are hard to control or describe for the ERP system. All subsystems of the manufacturing system work manually. Differences between operations and components that are used to assemble the final product demolish the possibility of any automatization in the company. Company A uses the individualized version of one of the standardized solutions of ERP solutions. It is open-source software and can be programmed according to the needs of the company.

Using an evaluation model that is created, company A is rated to be at the first level of integration (random integration). Enterprise of this level uses ERP algorithms similar to tools of Lean, but there is no purposive integration into Lean production.

Company A strongly emphasizes on the need of clearly described processes for the effective ERP integration into Lean Manufacturing. Complex and various manufacturing process can be seen as the biggest obstacle for ERP implementation. Although, the company has fully integrated a delivery module that has solved a problem of the delivery process is a bottleneck. All in all, company A is dealing with difficult problems, that does not allow to use the existing ERP system in full operation and reach II or even III level of integration. Although, it moves forward by maintaining its' practice and implementing new modules.

Company B is an SME company of Lithuanian industry. It has 240(2020-03-10) employees and 30–50 kk euros in sales revenue. The company specializes in design and manufacturing facades from aluminium, glass and other materials. Each project is different and has a lot of components, but processes for making those components are similar or the same. All subsystems of the manufacturing system work manually or using stand-alone machine tools. Although the similarity of the components creates a possibility of further automatization if manufacturing subsystem. Company A uses standardized ERP solutions. It is a solution that cannot be adjusted according to the requirements of the customer.

The evaluation of ERP integration into Lean Manufacturing is II level (purposive integration). Enterprise of this level purposefully improves and integrates their ERP system into Lean production. There can be indications of random integration of fully integration fragmentary observed.

Company B uses a wide package of modules that are being integrated into Lean Manufacturing. It advocated that the best way to integrate is to integrate all modules at once. Although it is a must to have a proper database before doing it. Company has an integrated ERP system at once with the beginning of the lean transformation in the company. In addition, it emphasizes that the ERP system gives very good data that are being used through the improvement activities. The biggest obstacles that appeared during the integration and appear now are related to workforce activity. They are human resistance and mistakes that were being done when reporting operations. Company has a lot of space to integrate their system into Lean Manufacturing and try to reach II or even III level of integration.

Company C is a company of Lithuanian industry. It has 510(2020-03-10) employees and 50–100 kk euros in sales revenue. The company specializes in the design and manufacturing of devices for movement (the common abbreviation). Company has its' own product and manufactures them for their customers. The manufacturing system is semi-automated. Some subsystems work automatically and some of them are manual. Although the similarity of the components creates a possibility of further automatization if manufacturing subsystem. Company C uses individualized ERP solution. The system is designed to optimize warehouse activity, internal logistics and to spectate internal indicators of the assembly line. A solution can be adjusted according to the requirements of the company.

The evaluation is the II level (purposive integration). Enterprise of this level purposefully improves and integrates their ERP system into Lean production. There can be indications of random integration of fully integration fragmentary observed.

Company C strongly emphasizes on the need of clearly described plan of the integration process and how important is to stick on to it. In addition, it emphasizes the importance of motivated implementation team that should be focused on the constant improvement of the system. Other features that are replicated as important

are top-management that follows the long-term goals and proper selection of IT solutions. The biggest obstacles for this company was the absence of the previously described team and human resistance. All in all, company C has done a great deal of work and progress while integrating to directions of production scheduling tools and tactics, tools for production process control and observation of the CSF and other indicators for the control of the processes. Proper experience and dedicated team open an opportunity for a company to reach II or even III level of integration.

Summarized results of the first part of the survey can be seen in the Table 1.

Main insights that can be noted after this part of the research are these:

- Directions of integration that gathered the biggest amount of points among all companies are tools for production process control and observation of the CSF and other indicators for the control of the processes. According to this research, they are very important or the easiest to integrate.
- The direction of integration that gathered the smallest amount of points among all companies is the observation of the production indicators for control and improvement. According to this research, they are less important or the hardest to integrate.

Table 1. Summarized results of the first part of the survey (source: prepared by author)

Direction of integration	Amount of points (Company A)	Amount of points (Company B)	Amount of points (Company C)	Sum
Production scheduling tools and tactics	0	1	3	4
Tools for production process control	2	2	3	7
Delivery planning methods	2	2	1	5
Observation of the CSF and other indicators for the control of the processes	2	2	3	7
Observation of the production indicators for control and improvement	0	2	1	3
Sum of the points and level of integration	6(I)	9(II)	11(II)	
The level of integration according the modules respectively to other companies	I (only warehouse)	III (Wide range)	II (Warehouse and manufacturing)	
Implementation cost (€)	30–50 kk	25–30 kk	60–100 kk	
Number of available, but not used features	4	2	3	

- Companies that are at the II level of integration replicates that ERP system and Lean Manufacturing should be started to implement at once. This could be one of the success factors of implementation.
- The majority of companies states that the biggest problem of the company was the inventory management in the warehouse and shop floor. This reason might be the catalyst for the decisions to integrate ERP system into a lean production system.
- A huge part of the obstacles that emerged in the implementation process is associated with human features. It leads to the statement that the success of the implementation leans on human resources.

These insights are used for creating the model of ERP integration into Lean Manufacturing

4. Analysis of empirical research (the second part of the survey)

Results of this part of the survey are presented by commenting on the averages of the answers for questions for revealing the most common positive outcomes and questions for revealing most important CSF.

The questions for revealing the most common positive outcomes. Significantly, the most important CSF that is rated with an average 9.1 is improved information management. Other leaders have scored 7.9 and 7.7 averages. They are improved decision making and planning quality. Third place can be split among positive outcomes of improved throughput of the production, improved throughput of the whole system and decreased stock in the warehouse of supply that scored 7.5, 7.2 and 7.4 averaged respectively. Other possible positive outcomes have scored averages below 7 and are considered as outsiders. Although, none of the outcomes has collected averages lower than 5. The lowest score was 5.7 of the outcome named reduced overall costs.

The questions for revealing the most important CSF. Because of the small standard deviation and range of averages, no significant tendencies can be seen when analyzing averages of the questions for revealing the most important CSF. CFS with biggest averages of 7.8 is monitoring and evaluating progress, having a project champion and clear implementation project timetable. Then follows top management support with an average of 7.7. Third place is divided among user involvement participation and having clear goals and objectives with an average of 7.3. Three outsiders are a changing culture in the company, user training and education and amount of financial resources respectively with averages 7.1, 7 and 6.4 respectively.

The analysis if the second part of the survey is presented using a Pearson correlation matrix. Cross analysis between two question blocks (questions for revealing the most common positive outcomes and questions for revealing most important CSF) has been done. CSFs that strongly correlated with positive outcomes of integration can be seen Table 2.

Table 2. CSFs that strongly correlated with positive outcomes of integration (source: prepared by author)

	Decision making quality	Info. mgmt	Production throughput	System throughput	Stock (raw)	Production costs
User involvement	0.702	Low or medium	Low or medium	Low or medium	Low or medium	0.742
Effective communication	0.718	Low or medium	0.787	0.856	0.811	Low or medium
Clear goals	Low or medium	0.843	Low or medium	Low or medium	Low or medium	Low or medium
Change culture	Low or medium	Low or medium	Low or medium	0.743	0.754	Low or medium

Main insights that are drawn from this table are:

- Most effective CSF of the implementation process is effective communication that correlated with four positive outcomes.
- Positive outcomes that can be easily achieved by holding on to certain CSFs are increased decision making quality (2 correlations), increased system throughput (2 correlations) and decreased raw material stock (2 correlations). Also, Information management can be improved (1 correlation) and production cost can be decreased (1 correlation) by holding on to certain CSF.
- Effective communication and change culture correlate with the same positive outcomes (an increase of system throughput and decrease of raw material stock). Those two CSFs complements each other.
- Effective communication might be associated with decreased resistance and fear of changes among the personnel that leads to better result of all system.
- Highest correlations are between effective communication and increased system throughput (*r*- 0.856), clear goals and improved information management (*r*- 0.843) and effective communication and decreased raw material stock (*r*- 0.811). It shows that the best and fastest way to reach mentioned positive outcomes is by concentrating on effective implementation process communication and clarifying implementation goals. It might be useful if there is a need for a quick win in the implementation process.

These insights are used for creating the model of ERP integration into Lean Manufacturing.

Also, the high effectiveness, medium effectiveness and low effectiveness CSFs can be found by calculating the sum of all correlation coefficients when correlating with the positive outcomes. It can be seen in the Table 3.

Table 3. The effectiveness of CSFs (source: prepared by author)

CSF	Sum of correlation coefficients	The effectiveness of CSF
Financial resources	1.704	Low
User training	4.196	High
Monit/eval progress	1.871	Low
Project champion	3.431	Medium
User involvement	4.253	High
Top management support	4.757	High
Effective communication	6.284	High
Clear goals	2.939	Medium
Change culture	5.086	High
Project timetable	0.843	Low

Main insights that are drawn from this table are:

- User training, user involvement, top management support and effective communication has high effectiveness on creating positive outcomes. Therefore those CSFs are critical for the success of the integration process.
- Having a project champion and having clear goals, has medium effectiveness on creating positive outcomes. Therefore those CSFs has medium importance for the success of the integration process.
- An amount of financial resources, monitoring and evaluating progress and having a project timetable has low effectiveness on creating positive outcomes. Therefore those CSFs has low importance for the success of the integration process.

These insights are used for creating the model of ERP integration into Lean Manufacturing.

5. The model of ERP integration into Lean Manufacturing

The aim of the model that is prepared in this project is to be a guideline for an ERP system integration into Lean Manufacturing system in the phase of implementation discussing the proper timeline and the most effective CSFs. Other phases (analyzing requirements, planning, choosing the vendor, etc.) are not considered except their results that are crucial or very important for successful implementation. The model consists of two parts. The first part of the model represents the recommended timeline of implementation (Figure 2).

The model starts with a description of a catalyst that might create an urgent need for the implementation of such a system. These catalysts are problems of inventory management in the warehouse and shop floor when it is

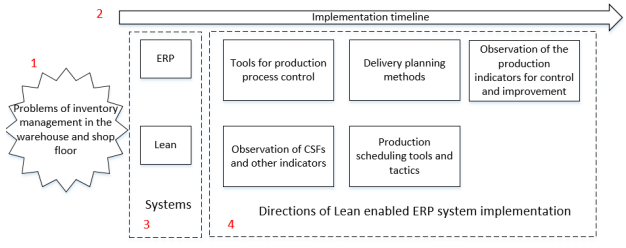

Figure 2. The first part of the model (source: prepared by the author)

very hard to control information and material flow on the shop floor and processes of the production (1). This catalyst was discovered during an analysis of the first part of the questionnaire in this research.

After the description of a catalyst that might create an urgent need for implementation of such a system, the timeline and implementation process starts. Implementation timeline shows time perspective from the start of the implementation process to the point in time when ERP is integrated into lean production in all directions of implementation (2).

The implementation process starts with a decision for the sequence of Lean and ERP systems implementation. According to the findings of this research, the best decision here is to start implementing Lean and ERP at once. It is shown parallel in time (3).

The implementation process continues with the sequence of directions of Lean enabled ERP system implementation into the manufacturing system. It is created according to the experience of companies that participated in the research. Their experience is considered as best practice. According to the findings of the research, companies were strongly advanced into tools for production process control and observation of CSFs and other indicators. The author states that it is because these were considered as crucial to overcoming business problems or the easiest ones to implement. A little bit less implemented were directions of delivery planning methods and production scheduling tools and tactics. The hardest one to integrate and the less integrated was the observation of the production indicators for control and improvement. Lower integration of last directions might occur because of lack of necessity, hardness to integrate or existence of substitutes in other IT systems of the company (4). All mentioned statements are made according to insights of this research.

The second part of prepared a model represents recommendations that should help to make the implementation process more effective, bring more positive outcomes to the company and avoid possible pitfalls (Figure 3).

The second part starts with a statement that the origin of the majority of the obstacles that appear during the implementation process is human resources. It is based on the findings of the research. Then the author suggests what it is needed to ensure that these origins would be diminished (1).

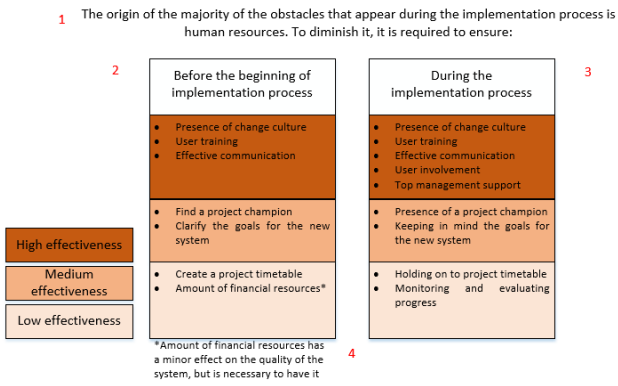

Figure 3. The second part of the model
(source: prepared by the author)

Than model shows what is required to ensure before the beginning of the implementation process (the execution phase). Three fill colours can be seen in the model. The intensity of the colour represents the effectiveness of each CSF of the implementation process for reaching positive outcomes. The effectiveness is rated by the sum of correlation coefficients when correlating with positive outcomes that can be found in findings of this research. It means that effective communication is much more effective than creating a project timetable of the amount of financial resources (2).

After that model shows what is required to ensure during the implementation process (the execution phase). Three fill colours can be seen in the model. The intensity of the colour represents the effectiveness (high, medium and low) of each CSF of the implementation process for reaching the positive outcomes. The effectiveness is rated by the sum of correlation coefficients when correlating with positive outcomes that can be found in the findings of this research. It means that it is wise to put more attention to user training than holding on to project timetable (3).

Model and with the adjustment for the CSF of the amount of financial resources that are invested in the implementation process. The author states that the amount of financial resources has a minor effect on the quality of the system, but it is necessary to have it (4).

This model is created to help manufacturing companies to implement ERP systems into their Lean Manufacturing system effectively as possible. It offers a timeline according to directions of implementation that is based on the good practice of companies that are already doing it. Also, it explains the effectiveness of each CSF for the implementation process. It is how the importance of the CSFs can be understood and used for the implementation process. The model is based on the findings of this research which are formulated and concluded by the author.

As it is stated in the introduction of this project, there is a need of fundamental guidelines that could help to lead companies to successful implementation not concerning about complexity of the system or price of a mistake. Model fulfils this need by suggesting the timeline of implementation and CSFs that are most effective when integrating the ERP system into Lean Manufacturing. It delivers detail information about the timeline of integration considering the start time of the implementation process of both systems and the timeline of integration of specific tools. This information is based on the findings of this research that are concluded by the author in this model. Furthermore, the model shows the CSFs of the integration process, their timeline of relevance and effectiveness to positive outcomes of the implementation process. This part of the model is also based on the findings of this research that are concluded by the author in this model. Mentioned model fulfils the need for a model that could lead companies to successful ERP integration into Lean Manufacturing.

Conclusions and proposals

As mentioned previously, the main object of this research is to fulfil the need for fundamental guidelines that could lead companies to successful ERP system integration into Lean Manufacturing for reaching competitive advantage not concerning about complexity of the system or price of a mistake. This research submits this objective by suggesting the model of ERP system integration into Lean Manufacturing.

Empirical research showed that the success of integration depends on various factors, but they can be assigned the type of production system and its' shortcomings. Companies that were analyzed, names a catalyzer for such implementation problems. It is problems with inventory management in the warehouse and shop floor. For companies with such problems, it is recommended to start the integration process by integrating tools for production process control and observation of CSFs and other indicators. Second directions that should be exploited are delivery planning tools and production planning tools and tactics. Finally, the direction of observation of the production indicators for control and improvement should be integrated. Also, it is worth mentioning insight that the origin of the majority of obstacles that appear during the integration process is human resources. Considering the CSFs that makes influence to positive outcomes of the integration process, user training, user involvement, top management support and effective communication CSFs has the highest effectiveness on creating positive outcomes. It is the reason why most of the resources should be intended to exploit them. Other CSFs and their relevance for positive outcomes are presented according to the timeline of implementation can be seen in Figure 3.

The proposed model could serve as a guideline for an ERP system integration into a Lean Manufacturing system in the phase of implementation discussing the proper timeline and the most effective CFSs. It will help manufacturing companies to implement ERP systems into their Lean Manufacturing system effectively as possible. Also, it offers a timeline according to directions of implementation that is based on the good practice of companies that are already doing it. Furthermore, it explains the effectiveness of each CSF for the implementation process.

It is very important to further investigate possible catalyzers for the integration process and create different timelines of the directions of integration for different catalyzers. It could create a scientific literature base for companies to solve their internal problems and gain a competitive advantage to their competitors by integrating the ERP system into Lean Manufacturing.

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ERP IR LEAN GAMYBOS SISTEMŲ INTEGRAVIMAS LIETUVOS PRAMONĖS ĮMONĖSE

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Santrauka

Šiomis dienomis aukštas konkurencingumas rinkoje verčia gamybos įmones ieškoti naujų būdų, kaip didinti savo konkurencinį pranašumą. Tai daryti galima mažinant gamybos išlaidas, mažinant gamybos ir pristatymo trukmę ar tampant lankstiems, gaminant įvairius produktus įvairiems klientams. Pats populiariausias būdas pasiekti išvardytų konkurencinių pranašumų yra įsidiegti „Lean“ arba ERP sistemas. Sėkmingas šių sistemų naudojimas gali tapti pagrindiniu įmonės sėkmės rodikliu ateityje. Šio tyrimo tikslas – sukurti ERP sistemos į „Lean“ gamybą integravimo gaires, remiantis tai jau padariusių įmonių gerosiomis ir blogosiomis patirtimis. Siekiant šio tikslo, bus išanalizuota mokslinė literatūra, susijusi su galimais kritiniais tokios integracijos veiksniais. Naudojant analizės rezultatus ir atliekant elektroninę apklausą bus atskleistas ryšys tarp jų ir galimų naudų, kurias sukuria šis integravimas. Taip pat sukurta ir išbandyta metodologija, skirta ERP sistemos integravimo į „Lean“ gamybą lygmeniui įvertinti.

Reikšminiai žodžiai: „Lean“ ERP, ERP integracija į „Lean“, ERP integracijos į „Lean“ kritiniai sėkmės veiksniai, Lietuvos pramonė.