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## Applicability of lean production with VSM to the Rioja wine sector

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### Abstract

Lean production arose as a step towards a new era in production systems. It is a working philosophy designed to produce better products using fewer resources to obtain greater benefits. It has been applied to a wide variety of sectors different from the original automotive industry, in which it was developed. However, its application to continuous manufacturing processes of continuous products has been less, especially to the wine production sector. The wine sector differs greatly to the automobile sector in various fundamental aspects but it also has common fundamental aspects in its production and logistics systems. An important part of this work has consisted in studying the wineries of the Rioja region. This article analyses the applicability of lean production in the La Rioja wine sector and the results that may be obtained from its application, using value stream mapping as the main tool to identify opportunities for improvement. This piece of research shows that most of the production problems in the wine sector can be tackled using a lean production system, making certain adjustments according to the type of production. It shows the main properties of wine production from the lean viewpoint, and it improves the production and logistics systems.

Keywords: Lean Manufacturing; Value Stream Mapping, Wine Industrial Sector

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## 1. Introduction

Lean production, also known as lean manufacturing, has been used by companies that wish to maintain their competitiveness in the market, obtaining better results while using fewer resources. The utmost objective of lean production is to eliminate all activities that do not add value throughout the production process. Originally, it was designed to produce cars in Japan, but its main techniques have been applied to a wide variety of other processes in both services and manufacturing.

Despite the diversity of applications in different production sectors throughout the world – cars, food, medicine and laboratories, etc - the lean production principles have been applied less in industries with continuous processes or continuous products, partly because of certain difficulties of implementation in this type of processes. Nevertheless, this fact does not mean that it cannot be applied. For example, in Mahapatra and Mohanty (2007) and in Abdulmalek and Rajgopal (2007) statistical analysis and a case study are used, respectively, to show that lean production is suitable for this type of processes and products. Nevertheless, today there is still a wide field of application in processes in which it has not been applied in all its possibilities, such as the wine sector, specifically that from La Rioja region in Spain.

The purpose of this piece of research is to show the applicability of lean production to the Rioja wine sector, and by extrapolation, to the large number of similar production systems of continuous products, such as production of oils, dairy products, etc. Note that wine production is not a continuous production but a batch production system, since although the product is continuous, the production is made in containers instead of a flowing stream of the materials (such as in glass, gas or petrochemical plants).

1  
2  
3 Value stream mapping (VSM) is used as the main tool to identify the wastes in the process,  
4  
5 developing a current mapping; subsequently a future map with the proposed improvements is  
6  
7 generated, as well as the working and annual revision plans, used to monitor the  
8  
9 implementation project (Chen *et al.* 2010).  
10  
11

12  
13 The proposed method is applied, as an example, to a fictitious winery (Bodega Marqués de  
14  
15 Galo), carefully designed as a representative model of most existing wineries, to demonstrate  
16  
17 the peculiarities and expected average results in the sector.  
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## 26 **2. Preliminaries. Application of lean production in the wine sector.**

### 29 **2.1. Brief history of lean production**

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33 As documented in Womack *et al.* (1990), after the Second World War, the most important  
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35 car company in Japan, Toyota, realised that mass production method (used in the United  
36  
37 States) was not suitable for financial, human resource, and market reasons, apart from  
38  
39 reasons regarding Japan government's economic policies; so, the engineers Eiji Toyoda and  
40  
41 Taiichi Ohno started the Toyota production system, later known as lean production. It can be  
42  
43 seen as an integrated social and technological system for improving processes, whose main  
44  
45 objective is to eliminate wastes and activities that do not add value to the client, obtaining  
46  
47 better productivity results.  
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52  
53 Toyota directors learned to work with small batches, to identify the value of each process and  
54  
55 the contribution of each activity to the most important person in the system, the end client.  
56  
57 They underwent a large reduction in machine change times. They offered good working  
58  
59 conditions to employees, guaranteeing them a lifetime job. They also sought to integrate both  
60

1  
2  
3 the supplier and the client in the process: the design of parts and production processes, the  
4  
5 delivery process to the end consumer and the establishment of long-lasting relationships with  
6  
7 them.  
8  
9

10  
11 This production system is characterized by qualified employees, grouped in work teams, with  
12  
13 the right to propose improvements. It encourages respect for the workers; it gives employees  
14  
15 the authority to stop production if an error or failure in the system is detected, and it always  
16  
17 pursues continuous improvement.  
18  
19

20  
21 Hines *et al.* (2004) point out that lean production has been extended considerably over its  
22  
23 lifespan, from automotive to manufacturing, and even to services, and they indicate, as a need  
24  
25 for research, to analyse how lean systems can be created in a 'green field' environment  
26  
27 (Rubio and Corominas 2008). The wine sector represents a virgin sector for lean production  
28  
29 techniques application, which will reduce environmental impact from its agricultural stage to  
30  
31 its distribution stage.  
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## 39 **2.2. Lean production techniques**

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41  
42 Lean production requires some tools to achieve its objectives, based on the Japanese word  
43  
44 Kaizen, which means continuous improvement. There is an extensive literature on this  
45  
46 subject: Monden (1996), Pavnaskar *et al.* (2003), Shah and Ward (2003), Holweg (2007), etc.  
47  
48  
49

50 The following techniques are noteworthy:

- 51  
52
- 53 • Kanban: this is a system for replacing material based on cards containing information  
54  
55 about the commands to execute, in order to deliver the correct order at the precise  
56  
57 moment.  
58  
59  
60

- 1  
2  
3 • Just-in-time (JIT): this is the set of practices based on the philosophy that companies  
4 should hold little or no inventory beyond that required for immediate production or  
5 distribution (Azadeh *et al.* 2010).  
6  
7
- 8  
9  
10  
11 • Cellular manufacturing: this is a way of organizing a process for a specific product or for  
12 similar products in a U-shaped group or cell that includes all the machinery, equipment  
13 and operators needed. A good distribution of the work improves the ability to handle daily  
14 fluctuations of assistance and demand in a typical factory.  
15  
16  
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- 18  
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20  
21 • SMED: this tool is used to reduce the time spent to change models in machines. SMED  
22 means “Single Minute Exchange of Dies”, and its basic idea is to change the production  
23 tools in less than 10 minutes, seeking to minimize the time spent on changing from one  
24 product to another or the machine time of maintenance. It is fundamental to reduce the  
25 size of production batches and to reduce downtimes.  
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- 30  
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32  
33 • Total Production Maintenance (TPM): it provides the workers with the basic regular  
34 working maintenance tools and the authority to respond to any anomaly, seeking to  
35 prevent problems instead of correcting them, and maximizing the availability of the  
36 production team and machinery.  
37  
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- 41  
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44 • Poka-Yoke: also called mistake proofing system, tries to create simple mechanisms so  
45 that operations can only be carried out correctly.  
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- 50  
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52 • 5 S production: it seeks improvements in the working area to facilitate the flow of  
53 materials and people, thus reducing errors and time: organisation, order, cleanliness,  
54 standardisation, and discipline.  
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- Lean production indicators (Visual aids): they monitor the progress of an improvement plan and provide information on each situation. These indicators must be visible to everyone. Some of them are on-time delivery, use of space, delivery time, cycle time, etc.
- Value stream mapping: also called "material and information flow mapping", is a tool that uses icons and graphics to show, in a single figure, the sequence of the flow of material and information of all components in the value stream, including the manufacturing process, suppliers and distribution to the client (Seth and Gupta 2005).

VSM has been the main technique used in this work, since as lean production has not been applied before to the wine sector, the knowledge of the production system from the lean point of view, based on the material in information flows, can constitute a very useful tool as well as the basis on which apply the other techniques. Furthermore the graphical representation of this technique allows showing the results to the decision makers in the wineries, although they are not specialist in lean production.

VSM not only handles a specific process, but also provides an overall view of the entire system, seeking to optimize it as a whole. According to Rother and Shook (2003), it is a "door-to-door" representation including the production process and the prior and later logistics. It is a guide to start implementing the lean production principles, since it designs an ideal future state of the entire process, and it is useful and applicable for redesigning production systems, as Serrano et al. (2008) illustrate.

VSM helps to understand the flow of materials and information through the production system in a common language, where the other lean production tools can be used to achieve a future or ideal situation. It includes the collection of all of the activities that add and do not



1  
2  
3 add value and that are carried out to obtain a product (or group of products that use common  
4  
5 resources).  
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8  
9 The first step is to choose the product or family of products to be improved. The current  
10  
11 situation of how things are managed at the time of the analysis must then be mapped. The  
12  
13 third step is to create a map of the desired future state after eliminating the wastes in the  
14  
15 process. To achieve this, it is necessary to answer a series of questions that help to identify  
16  
17 the points for improvement. Finally, a working plan with periodic revisions must be prepared  
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19 to monitor the implementation of the improvements.  
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### 28 **2.3. Application to a representative winery in La Rioja**

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30 An important part of this piece of research has consisted in studying the wineries of the Rioja  
31  
32 Qualified Designation of Origin (Rioja 2010) in order to determine a winery that represents  
33  
34 them, and to assess the degree of representation on the sector. The analysis led to determine  
35  
36 said winery and to check that the methodology, considered and applied to it as an example, is  
37  
38 valid for all the wineries in the Rioja wine sector.  
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43 The selection of the wineries was made from the total directory of Rioja wineries (Rioja  
44  
45 2010). There exist 598 registered wineries, and in 2009 our University research group sent an  
46  
47 email to the 339 that provided email addresses. Only 35 of them agreed to collaborate, and 26  
48  
49 of these 35 were family wineries, the most prevalent type of winery in Rioja and the most  
50  
51 appropriate for improvements, because usually they do not make effort in research and  
52  
53 development (R&D) and optimization. From the 26 family wineries, we selected the 10 that  
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55 we decided represented the sector range, according to quantitative criteria (in particular the  
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57 necessary vineyard surface, the annual sales, the annual wine production, and the number of  
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3 workers in the process stream) and qualitative criteria (in particular the clarifying method, the  
4 use of carbonic fermentation, and the malolactic fermentation in tank or barrel). These  
5 criteria were determined with the collaboration of several oenologists in the region. The  
6 sample was validated by calculating the average and the mode of the quantitative and  
7 qualitative criteria respectively, corresponding to all of the wineries with the Rioja Qualified  
8 Designation of Origin that provided us with information, obtaining results similar to the  
9 sample of only ten wineries.

10  
11  
12 Our representative fictitious winery was defined by selecting its values of the quantitative  
13 criteria from the average of the values for the ten sample wineries, and the qualitative criteria  
14 were determined by majority, selecting the most repeated value in the sample, i.e. the mode.

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Table 1 shows the characteristics of the 10 representative family wineries, as well as the  
average of all of them, and the selected main properties of the fictitious representative  
winery. All of them work for five days a week with two eight-hour shifts each day. The  
information of the 10 wineries has been obtained from the oenologists and the people  
responsible for production, by cooperation of the wineries with our research group; the  
wineries provided the research group with the information of its production processes, and  
the group provided the wineries with the results of the lean analysis and helped them in the  
subsequent application.

Table 1. Information about the selected wineries.

Later on, the results obtained with our fictitious winery were validated with an analysis of the  
benefit of the lean production techniques application on each one of the ten wineries. The

1  
2  
3 results (production lead time reduction and expense reduction in raw material purchase) were  
4 compared with the obtained with the fictitious average winery, detailed in this paper. In  
5  
6 summary, the results were similar with those of the sample wineries and with the average  
7  
8 winery (in percentage terms), so the representativeness of our fictitious winery was  
9  
10 guaranteed.  
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15  
16 The fictitious winery that represents the wineries in the sector, taken as a model to apply the  
17  
18 proposed methodology, is called Marqués de Galo, belongs to the Rioja Qualified  
19  
20 Designation of Origin, and it is a family winery that prepares young, mature and reserve red  
21  
22 wines, as well as young white wines. The average demand per year is 145,600 bottles of  
23  
24 young red wine (2800 per week or 560 per day). The winery works for 52 weeks a year and  
25  
26 five days a week, with two eight-hour shifts each day. Red wines, young, mature and reserve,  
27  
28 differentiate basically by treatment, rather than material components, and they present  
29  
30 differentiate inventories. The young red wine has been chosen as the process to exemplify the  
31  
32 methodology, in order to simplify the results, although the methodology is totally similar for  
33  
34 all the types of wine. The inventories and times correspond just to this type of wine, as well  
35  
36 as the Figures and results, but these results can be extrapolated to the other types.  
37  
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43 Only to point out the determination of the production sequence, in a following section, all the  
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45 types of wines have been used in this paper, because for this task it is necessary to deal with  
46  
47 all the types of final products of the production system.  
48  
49  
50

51 The process for this product starts when the grapes are received in September, in 3,000 kg  
52  
53 trucks. The grapes are then weighed, their properties inspected, and they are deposited in a  
54  
55 stainless steel hopper of triangular cross section. It is used to feed and regulate the entry of  
56  
57 the grapes in the stalk remover machine with a worm gear, before reaching the crushing  
58  
59 machine. Pumps are used to move the must and crushed paste through pipes to fermentation  
60

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3 tanks or other machines such as the press. All the fermentation tanks are made of stainless  
4  
5 steel with a capacity of 35,000 litres, but they are filled up to 28,000 litres. Alcoholic  
6  
7 fermentation takes place first, followed by malolactic fermentation. In the press the mass is  
8  
9 squeezed between two plates perpendicular to the floor, and the must runs down the sides.  
10  
11 Before being bottled, the wine must be clarified and earth-filtered. The bottling area contains  
12  
13 machines for washing bottles, bottling the wine, corking, encapsulating, labelling and  
14  
15 packing.  
16  
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20  
21 The winery communicates with its clients and distributors by telephone for orders, and to buy  
22  
23 its raw material and other materials used in the process. Production and planning are the  
24  
25 responsibilities of the owner of the winery together with the oenologist, who is responsible  
26  
27 for the quality and the properties that personalize the wines and for reporting and authorizing  
28  
29 what must be produced in each process. This leads to a lot of parallel information flow.  
30  
31  
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33  
34 The production is annually planned but, depending on the grapes' quality through the  
35  
36 production process, short-term estimates and modifications are made. In the bottling area,  
37  
38 estimates are made three months beforehand and orders are sent out weekly. The winery has  
39  
40 no type of planning for buying raw materials such as sulphur, bottles, corks, eggs or water,  
41  
42 buying them as needed.  
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### 50 **3. VSM Development**

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54 To implement lean production on the representative system described in the previous section,  
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56 VSM will be used as the basic tool.  
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59  
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### 3.1. Current VSM

After choosing the product and carefully collecting the information (Rother and Shook 2003) the map of the current situation was developed. Figure 1 shows the resulting current map.

Figure 1. Present value stream mapping

VSM represents information and material flows.

Information flow:

- The straight arrows represent manual information between processes. The owner and the oenologist are the responsible for every process; so they have the role to inform and permit each production process. This implies a large information flow in parallel.
- The broken arrows represent electronic information. Customers and distributors make the orders by telephone, and the winery buys in the same way the raw materials and other materials used in the process.

Material flow:

- The squares represent each operation with data such as the number of workers, the cycle time (CT), inventory before each process (below the triangles) and raw material in the process (RM) from the area where the grapes are received to the sales area. The cycle times are average times for each process. In our Figures the following processes have been represented: Grape harvest Receipt & test of characteristics, Grape harvest receipt in winery,

1  
2  
3 Stalk removal and crushing, Sulphitation, 1st Fermenting, 2nd Fermenting, Pressing,  
4 Clarifying, Filtering, and Bottling-corking-encapsulating-labelling&packing.  
5  
6  
7

- 8  
9 • The icons of the top part represent external sources. The right part represents the  
10 customers, where it is shown information about the demand, the takt time, the shifts (first  
11 shift from 6:00 to 14:00, and second shift from 14:00 to 22:00) and the workers directly  
12 working in the winery. The left part represents the providers and the different raw materials.  
13  
14  
15  
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18  
19 • The triangles represent the inventory before every process.  
20  
21  
22  
23 • The lorries represent the raw material transport to the winery and the transport of final  
24 products to the customers.  
25  
26  
27  
28  
29 • The thick dark arrows represent the in-process material that is pushed to a production  
30 process to the next one.  
31  
32  
33  
34 • The thick white arrows represent the in-process material that is pulled from a  
35 production process to the above process.  
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43  
44 The timeline at the bottom of the figure consists of two elements:  
45

- 46  
47 - Production lead time, which is the sum of the inventories' lead times. The inventories'  
48 times are obtained by dividing the total inventory by the daily demand of the clients (Mikati  
49 2010, Hayya and Harrison 2010). The total production lead time obtained is 440.11 days.  
50  
51  
52  
53  
54  
55 - Time of activities that add value (processing time), which is obtained by summing the  
56 cycle times for each process. The resulting value-added time is 31 days, representing 7% of  
57 the total production lead time. For non-experts in VSM, a deep knowledge of the graphics,  
58  
59  
60

1  
2  
3 icons, and arrows of Figures 1 and 2 can be consulted in any publication about VSM and lean  
4  
5 production, as for instance Rother and Shook (2003).  
6  
7  
8  
9

### 10 11 12 **3.2. Future VSM** 13 14

15  
16 With the map of the current situation, the problems and wastes start to appear. Figure 1  
17  
18 shows large inventories, the large production lead time compared to the value-added time,  
19  
20 and a lot of parallel planning information. To reduce or eliminate these problems, a series of  
21  
22 questions are raised that facilitate the understanding of the current flow and the establishment  
23  
24 of a continuous flow between all the processes.  
25  
26

#### 27 28 29 **Which is the *takt* time?** 30 31

32  
33 The *takt* time is the maximum time allowed to produce a product in order to satisfy the  
34  
35 demand. Initially, a product must be defined, and in our process it is a 0.75 litre bottle. The  
36  
37 *takt* time is calculated by dividing the available hours of work into the product demand. In the  
38  
39 winery, 288,000 seconds a week are worked (five days of eight hours with two shifts). The  
40  
41 non-productive hours must be subtracted from this, specifically one hour per shift for meals  
42  
43 and rests. The available time is divided into the demand for the young red wine, 2,800 bottles  
44  
45 a week, to give a *takt* time of 78 seconds.  
46  
47  
48

#### 49 50 **Is the production for a finished product stored where the client will make his orders or** 51 52 **will it be sent directly to the sales area?** 53 54

55  
56 Production for sending directly to the sales area means that only the necessary units for  
57  
58 sending to clients will be produced. Currently, the winery produces the bottles of wine, and it  
59  
60 sends all of them to a store where they await being sold together with other products. This

1  
2  
3 production system is known as 'push system', and its main problem is that the product may  
4 remain for a long time waiting for being processed. It is proposed to produce according to a  
5 kanban system, and the production can be sent to a 'supermarket' type of store that is a place  
6 at the end of the production system for storing products ready for sales. When the inventory  
7 in the store is below a certain amount, the store alerts the bottling process to produce more  
8 bottles of wine.  
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### 18 **Where must the continuous flow be used?**

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21 Because of its large tanks and machines, the production process under study cannot easily be  
22 arranged in the form of a classical cellular manufacturing system. Besides the production  
23 process is to a certain extent different to that of a typical factory, because the product depends  
24 greatly on the quality of the grape, and times and performance of the production tasks may  
25 vary from one season to another.  
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34  
35 The processes involved from the entry of the grape in the winery to fermentation area are by  
36 nature a continuous flow. Nevertheless, a continuous flow cannot be used after fermentation  
37 because its cycle time is too long compared to the other processes. Later, in the bottling area,  
38 a continuous flow can be applied again for bottling, corking, encapsulating, labelling and  
39 packing. This final process will be the regulator process, and more details about it will be  
40 given below. Thus, when the proposed supermarket is below a certain level, it will request  
41 the bottling process and it must produce again for inventory turnover.  
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### 52 **Where is a 'pull system' needed for production control?**

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55 The introduction of a production 'pull system' is necessary when: a) some processes have  
56 long maturing times or if connecting them to other processes in a continuous flow is not  
57 profitable; b) some of the suppliers are far away from the company or it is necessary to make  
58  
59  
60



1  
2  
3 large orders for other reasons. As well as the proposed 'supermarket system', two additional  
4 storage areas are proposed, one at the start of the process to receive the grapes, and the other  
5 after the filtering process. The first store will be used as an indicator for the person  
6 responsible for ordering the grapes or other necessary raw materials in order to avoid running  
7 out of supplies or receiving unnecessary material. The second supermarket is proposed before  
8 the bottling operation, immediately after filtering. The filtering process currently pushes the  
9 production into the bottling process, creating inventory in the process. With the proposed  
10 'pull system', the bottling process will request the filtering process when it needs more  
11 product.  
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26 **What point in the production stream will be used to organize the production (called the**  
27 **regulator process)?**  
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31 When using 'pull systems', it is necessary to schedule the production of an only process  
32 throughout the stream, called the regulator process. All processes upstream of the regulator  
33 process will work under a 'pull system', and the flow of processes downstream will be  
34 continuous. The regulator process in this study is the bottling area, since it is the last stage  
35 and it sets the basis for the final production. After this process, the FIFO (first in, first out)  
36 system will be used.  
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46 **How can production be scheduled in the regulator process?**  
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50 The reason for this question is that production must be distributed uniformly when preparing  
51 different products. In the winery under study, various types of products are made, including  
52 the young (YR), matured (MR) and reserve (RR) red wines and the white wine (WW). It is  
53 necessary to plan how much has to be produced to avoid inventory in the process and, above  
54 all, the most important of all wastes, over-production. We have used a formula proposed by  
55 Monden (1996) to determine the production sequence:  
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$$D_{ij} = (j-0.5) \cdot (T/D_i) \quad i=1,2,\dots,n \quad j=1,2,\dots,D_i \quad (1)$$

where  $n$  is the number of different products to be produced,  $D_i$  is the daily demand for each product  $i$ ,  $T = D_1 + D_2 + \dots + D_n$  is the total daily demand,  $j$  is the unit number of the product  $i$ , and  $D_{ij}$  is the ideal production position for the unit  $j$  of product  $i$  in the sequence.

In this case,  $n=4$ , and the values of  $D_i$  are 560, 520, 200, and 80, for YR, MR, RR, WW, respectively.  $T$  is the total demand of 1360. Table 2 shows the production sequence obtained with equation (1). Analysing the result, it can be seen that a production pattern is created (YR, MR, RR, YR, MR, YR, MR, YR, WW, MR, RR, YR, MR, YR, MR, YR, MR, RR, YR, MR, YR, MR, YR, RR, MR, YR, WW, MR, YR, MR, YR, RR, MR, YR), (YR, MR, RR, YR, MR, YR, MR, YR, WW, MR, RR, YR, MR, YR, MR, YR, MR, RR, YR, MR, YR, MR, YR, WW, MR, RR, YR, MR, YR, MR, YR, MR, RR, YR, MR, YR, MR, YR, RR, MR, YR), etc. This allows the sequence to be simplified by grouping equal products to just (14 YR, 13 MR, 5 RR, and 2 WW).

Table 2. Production sequence.

The proposed production sequence (14 YR, 13 MR, 5 RR, and 2 WW) derived from Table 2 indicates the order in which the different types of wine have to be finished in the production system; some processes depends on parameters such as the climate or the date, and can not be delayed or moved forward more than some weeks or days, but the final product can be appropriately planned. Note that as the mature and reserve wines spend several years in production (lying in the barrels and the bottles), so the inventory has to be high enough to allow it, and the products of such types provided in the production sequence (13 MR and 5 RR) started their production years ago.

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3 The previous production sequence has been obtained from the relationship amongst the  
4 different types of products in the winery, which depends on the demand. One of the ways to  
5 manage demand in order to avoid overproduction in systems with different finished goods is  
6 through delayed differentiation (or postponement), a methodology in which some of the  
7 activities in the supply chain are not performed until customer orders are received; that  
8 allows finalizing the output in accordance with customer preferences and even customizing  
9 the products (Hoek van 2001, Yang *et al.* 2004). This methodology can be a tool to manage  
10 the demand uncertainty within the wine sector, as shown by Cholette (2009).  
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23 **What improvements will be necessary in the process value stream so that it flows as**  
24 **specified in the design for the future state?**  
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29 One of the problems of the winery is that it loses a large part of the raw material that it  
30 receives - the grapes - due either to the inefficiency of the machines or to the quality of the  
31 grapes. Therefore, it must receive much more grapes than necessary for its demand. It is  
32 evident that the processes must be improved to avoid wasting material along the route and to  
33 buy only the raw material that will be used.  
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42 To attain the desired flow of materials and information, some changes and actions must be  
43 carried out:  
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- 47 - The current press must be changed for a horizontal membrane press, which is more  
48 efficient and can halve the time needed to press the mass of grapes.  
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- 53 - The total production lead time can be reduced by eliminating or reducing the inventory of  
54 material in process.  
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- 58 - The current earth filters must be changed for membrane filters, since these provide better  
59 quality and cleaner wines, also saving the time taken to filter the liquid.  
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- The use of visual aids and '5s system' in all areas of the process would greatly help to avoid errors caused by confusion and time spent identifying tasks.
  - Standardisation of processes also reduces the production lead time.
  - The use of a kanban-based purchasing system for other raw materials used in the process such as sulphur, eggs, bottles, corks, labels and boxes, will avoid running out of inventory at any given moment (Claudio and Krishnamurthy 2009).
  - The creation of long-lasting relationships with suppliers, encouraging them to work with a lean production system too, is also positive for the winery.
  - The proposed stores will change some departments, and the information flow with managers will be reduced.
  - Materials and tools must be placed near the processes where they are used.

The map of the future state is shown in Figure 2, stressing the potential areas for improvement with stars. With these improvements, the total production lead time is now 162 days. This means that the value-added time is now 19% of the total production lead time, while in the original state, modelled by the "current state map", it was only the 7%. The improvements have reduced the inventory in the process and the overproduction.

Figure 2. Future value stream mapping

From this new Figure of the future VSM, it can be observed that:

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3 • The figure of inventory with withdrawal kanban cards (dark) and production kanban (white)  
4 represents a supermarket, in which every process is asked by its next process about the  
5 requirements of product quantities and the disposal time.  
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11 • The Y is a type of Kankan that alerts the person responsible for requesting the grapes and  
12 other necessary raw materials when the level is lower than a certain parameter, in order not to  
13 stop receiving at any moment and not to take unnecessary material.  
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17 • The FIFO system represents that in the next process the work will be developed according  
18 to the arrival order.  
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21 • And in the timeline at the bottom of the figure it is showed that:  
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25 - The production lead time in the present VSM was 440.11 days, while with the  
26 proposed improvements the future VSM gives 162 days.  
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30 - The value-added time in the present VSM was 31 days, which represents 7% of the  
31 total production lead time, and in the future VSM it is also 31 days, but now it represents  
32 19% of the total. There is less inventory in the process, and overproduction is reduced. In  
33 section 4 the quantitative results of this Future VSM of Figure 2, are more deeply analysed in  
34 comparison with the previous Present VSM of Figure 1.  
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### 46 **3.3. Definition and implementation of the working plan.**

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51 To attain this future state it is necessary to set up a working plan and to organize into stages  
52 the changes to be made. Figure 3 shows the proposed loops and the annual schedule proposed  
53 is detailed in Table 3. In the first loop the regulator process is improved, because bottling  
54 process determines the production speed. Then the second loop is used to design the raw  
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3 materials reception system with the suppliers, and the last loop improves the flow between  
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5 reception in the winery and bottling process.  
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11 Figure 3. Loops map  
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14 Table 3. Annual Schedule  
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### 18 19 **Loop 1: Regulator process loop** 20

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22 A continuous process must be generated in this loop, from filtering to shipping. The kanban  
23 and FIFO systems in the bottling area must also be calculated in detail, allowing only 0.1  
24 days of inventory in the finished product store. The estimated loop duration is three months,  
25 and its activities can be achieved in parallel.  
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### 33 **Loop 2: Loop with the supplier** 34

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36 This stage will be devoted to developing a 'pull system' with the grape reception store and  
37 with the other raw materials purchased to prepare the product, allowing just 0.1 days of  
38 inventory. The purchasing system will consist in having a minimum inventory level, and  
39 when it drops below this level, it will generate a purchase order for the material needed,  
40 instead of waiting for it to run out before ordering it. A commitment of long-term working  
41 commitment must also be taken between suppliers and winery, setting up programmes for  
42 mutual benefits and teamwork. The estimated loop duration is two months after loop 1.  
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### 53 **Loop 3: Flow loop** 54

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56 In the next seven months, we propose to achieve the continuous flow by setting up a  
57 production 'pull system' between the stations in order to reduce inventory, using visual aids  
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3 in various areas and installing production and progress graphics. These latter will show  
4 everyone the goal to be attained and the accomplished weekly work so every employee can  
5 know the company situation, feeling engaged to work to attain its objectives. It is also  
6 proposed to apply the '5s system' throughout the installation to standardize the work area, to  
7 keep it clean and tidy and to acquire new machinery (press and filters). As well as the above  
8 proposals, it is necessary to create continuous improvement teams that are responsible for  
9 putting into practice projects developed to eliminate all types of waste and to make tasks  
10 increasingly efficient.  
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15 To monitor the working plan, a revision plan is recommended to assess its operation and  
16 progress. It is proposed to carry out the first revision after six months, when the first two  
17 stages must be over. Responsible people and deadlines must be set for carrying out each stage  
18 of the project.  
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#### 36 **4. Results of lean production in the sector**

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40 The expected results for the sector after this piece of research and analysis of the application  
41 of lean production techniques to produce wine in La Rioja, can be deduced from the data in  
42 the previous Figures, especially by comparing Figure 1 with Figure 2.  
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48 Apart from the qualitative differences that appear in Figure 2 (timing planning, supermarket,  
49 FIFO and pull systems, etc.) which have been previously explained, and which are indicated  
50 by stars in Figure 2, the main quantitative result is the reduction of the production lead time  
51 from 440,11 to 162,5 days. But the analysis permits us determine the processes in which the  
52 reduction has been more significant. Table 4 shows the difference of CT, RM and inventory  
53 from the present VSM to the future VSM.  
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Table 4. Quantitative comparison of present (P) VSM with future (F) VSM

The main reduction in raw material is obtained from the Clarifying & Quality test process, and the main reduction in inventory is produced in the processes:

- Grape harvest Receipt & test of characteristics
- Grape harvest Receipt in winery
- Stalk removal and Crushing
- 1st fermenting & Quality test
- 2nd fermenting & Quality test
- Clarifying & Quality test
- Filtering
- Bottling, corking, encapsulating, labelling & packing

The previous analysis shows that lean production, applied to the sector, will:

- Reduce the total production lead time by 60%.
- Reduce the purchase of raw materials by 13%, therefore a saving of 49,500 € per year for an average winery.
- Eliminate losses and deterioration of material while processing.
- Reduce the amount of information between processes.
- Allow a better use of the physical space and machinery in the winery.
- Achieve a better distribution of work among operators.



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3 Note that the proposed methodology does not reduce the useful time expended in every  
4 process, but the wasted time; in fact, quality is the main objective of Rioja wine producers,  
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6 and the improvements will only be taken into account if they do not endanger the quality. The  
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8 proposal has been developed by a multidisciplinary team that includes the oenologists of the  
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10 wineries, who ensure that premise.  
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19 The results have been obtained from the simulation on the fictitious representative winery.  
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21 Those results have been validated with the simulation in the 10 real wineries, in which the  
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23 simulated results were different among them (depending on the initial inventory level and the  
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25 communication between processes basically) but in a similar range of improvement (raw  
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27 material reduction from 8% to 16% and production lead time reduction from 50% to 65%).  
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29 The results presented have also been validated by the application of the methodology and the  
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31 working plan on one of the wineries, the sixth winery from Table 1; this winery, Viña  
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33 Valoria, was chosen because it was the most similar to the representative one. In two other  
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35 wineries (numbers 7 and 10 from Table 1) the implementation is finishing, with results also  
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37 in agreement with what the simulation predicted. The rest of the wineries have started the  
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39 process.  
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46 Various lean production techniques related with lean production can be adopted, as shown in  
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48 Table 5, which summarize those whose applicability has been analysed throughout this piece  
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50 of research. The first three tools - 5S, visual aids and kaizen - are universally applicable, i.e.  
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52 applicable to produce any product or service in any sector. VSM and TPM are applicable to  
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54 the complete process in the wine sector. Kanban, JIT, and SMED can only be applied to  
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56 certain pieces of the wine production stream, and Cellular Manufacturing is probably  
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58 inapplicable because the machinery and the tanks are usually too large. The applicability of  
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3 all the previous techniques in the wine sector has been analysed, and then they have been  
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5 applied in order to verify the results. The application has been previously simulated into the  
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7 fictitious representative and the 10 real wineries, and subsequently, it has been developed in  
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9 the rest of the selected wineries (in one of them, the most similar to the fictitious  
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11 representative one, the application is finished, and in two more the application is very  
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13 advanced).

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19 Table 5. Assessment of lean tools in the wine sector.  
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## 21 22 **5. Conclusions**

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25 The applicability of lean production techniques in the Rioja wine sector has been presented. It  
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27 is aimed at improving the production process efficiency.  
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31 Firstly, the sector has been analysed, and a winery has been proposed, which is representative  
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33 of the sector regarding its properties and the application of lean production. VSM has been  
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35 used as the main tool to identify process wastes in the sector, and the present and future maps  
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37 have been developed, as well as an analysis of the estimated results of the application in the  
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39 wineries.  
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44 This sector is very different to the automobile sector, the cradle of lean production, but  
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46 nevertheless, the results show that the concept is applicable to this sector simply by adapting  
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48 its working methods. Some of the lean production techniques have proved to be perfectly  
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50 applicable, providing very satisfactory results, while others are only partially applicable or  
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52 even inapplicable, due to the nature of the production sector, but in any case, the application  
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54 of lean production attains substantial improvements.  
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59 Finally, as an example of the application of the methodology, a plan has been developed to  
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implement it in one year, structured in three stages to facilitate its application.

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3 The key issues derived from the proposed methodology, those that can be considerably  
4 improved by its application, are: the inventory reduction, the appropriate information  
5 management and elimination of the redundant information, and the use of advanced  
6 technologies. These problems, which were present at all the analysed wineries, can be  
7 considered the key for the extrapolation of the proposed methodology and the expected  
8 results to other alimentary sectors, specially of liquids products, such as oil, dairy, etc.  
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Winery	Weekly sales of YR in 750 ml bottles	Types of wines	Percent of YR sales (by volume)
1	1700	YR, MR, RR	27
2	2100	YR, MR, RR, WW	24
3	2450	YR, MR, RR, WW	33
4	2650	YR, MR, RR	36
5	2680	YR, MR, RR, WW	38
6	2800	YR, MR, RR, WW	42
7	2920	YR, WW	55
8	3390	YR, MR	57
9	3550	YR, MR, RR, WW	48
10	3750	YR, MR	65
Average	2799		41,18
Representative	2800		41,18

(YR young red, MR matured red, RR reserve red, and WW white)

Table 1. Information about the selected wineries.

Product	$i$	$D_{ii}$	Sorted $D_{ii}$	Product	$i$
YR	1	1.21	1.21	YR	1
YR	2	3.64	1.31	MR	1
YR	3	6.07	3.40	RR	1
....	....	....	....	....	....
YR	55	132.36	54.64	YR	23
YR	56	134.79	56.23	MR	22
MR	1	1.31	57.07	YR	24
MR	2	3.92	57.80	RR	9
MR	3	6.54	58.85	MR	23
....	....	....	....	....	....
MR	51	132.08	105.92	MR	41
MR	52	134.69	108.07	YR	45
RR	1	3.40	108.54	MR	42
RR	2	10.20	110.50	YR	46
RR	3	17.00	110.50	WW	7
....	....	....	....	....	....
RR	19	125.80	126.85	MR	49
RR	20	132.60	127.50	YR	53
WW	1	8.50	127.50	WW	8
WW	2	25.50	129.46	MR	50
WW	3	42.50	129.93	YR	54
....	....	....	....	....	....
WW	7	110.50	134.69	MR	52
WW	8	127.50	134.79	YR	56

Table 2. Production sequence.

Loop	Objectives / Months	1	2	3	4	5	6	7	8	9	10	11	12
1	Continuous flow	■	■	■									
	Kanban and FIFO calculation	■	■	■									
2	Pull system definition with the suppliers				■	■							
3	Pull system definition between stations						■	■	■				
	Visual aids definition						■	■	■	■			
	5 S system definition						■	■	■	■			
	New machinery acquisition, TPM									■	■	■	
	Start the production system, SMED											■	■
	Teams for Continuous Improvement												■

Table 3. Annual Schedule



PROCESS	P Invent.	F Invent.	P CT	F CT	P RM	F RM
Grape harvest Receipt & test of characteristics	2800	50	0,92	0,92	2800	2800
Grape harvest Receipt in winery	2800	50	0,54	0,54	0	0
Stalk removal and Crushing	2800	50	0,68	0,68	0	0
Sulphitation & Quality test	1400	1400	300	300	50	50
1st fermenting & Quality test	56000	30000	1296000	1296000	0	0
2nd fermenting & Quality test	46000	23000	1296000	1296000	0	0
Pressing	10000	10000	900	500	0	0
Clarifying & Quality test	54000	26500	87000	87000	30000	300
Filtering	54000	200	30	30	0	0
Bottling, corking, encapsulating labeling & packing	253	0	262	262	18575	3700

Table 4. Quantitative comparison of present (P) VSM with future (F) VSM

Lean production tools	Applicability
5 S	Universally applicable
Visual aids	Universally applicable
Kaizen	Universally applicable
Value Stream Mapping	Applicable
Total Production Maintenance	Applicable
Kanban	Partially applicable
Just-in-time	Partially applicable
SMED	Partially applicable
Cellular manufacturing	Probably inapplicable

Table 5. Assessment of lean tools in the wine sector.

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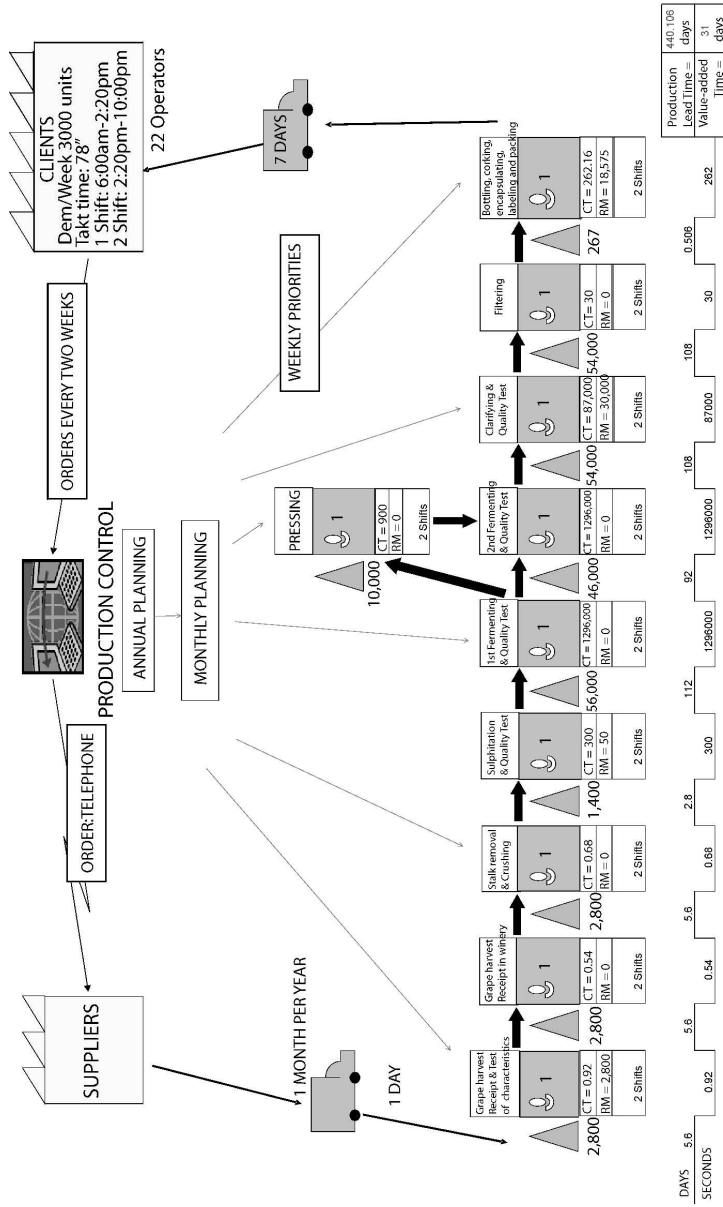
**Figure captions:**

Figure 1. Present value stream mapping

Figure 2. Future value stream mapping

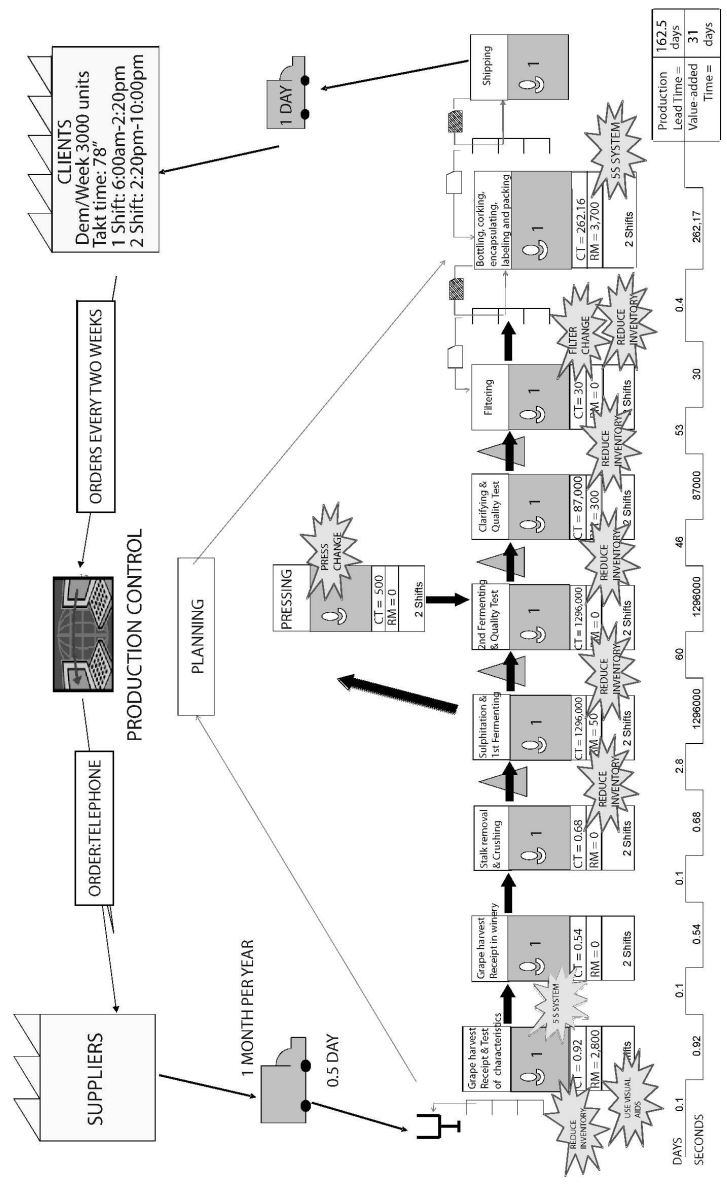
Figure 3. Loops map

For Peer Review Only

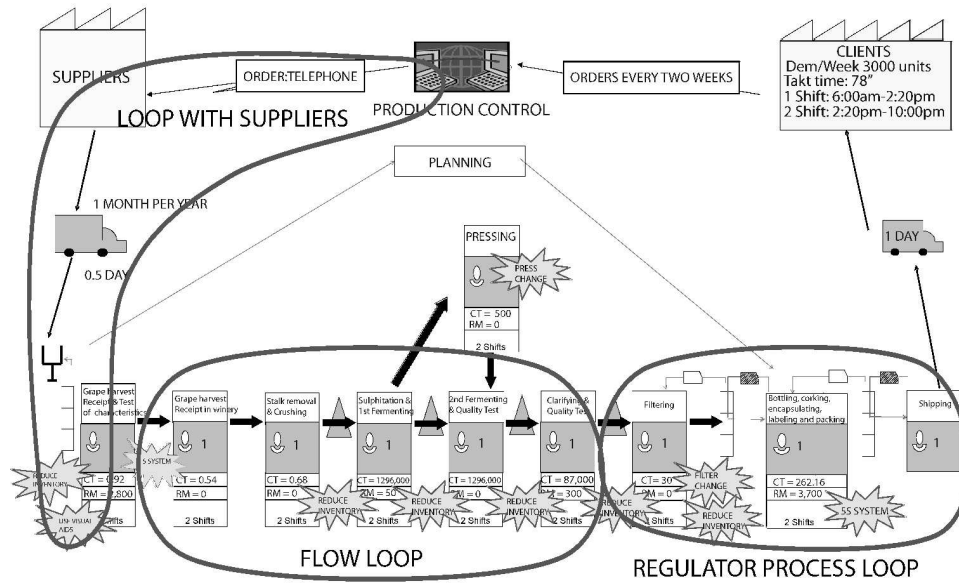


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200x126mm (600 x 600 DPI)