A cluster analysis of companies implementing lean principles in Europe

Antomarioni S.*, Bevilacqua M.*, Ciarapica F. E.*, De Sanctis I.*, Ordiéres J.**

* *Department of Industrial Engineering and Mathematical Science, Università Politecnica delle Marche, Ancona, Italy (s.antomarioni@staff.univpm.it, m.bevilacqua@staff.univpm.it, f.ciarapica@univpm.it, il.desanctis@gmail.com)*

** *Department of Industrial Engineering, Business Administration and Statistics, ETSII, Universidad Politécnica de Madrid, Madrid, Spain (j.ordieres@upm.es)*

Abstract: This paper aims at analyzing barriers encountered by firms in implementing lean projects and at classifying them according to the degree of difficulties experienced. In accordance with a literary review, lean barriers can be bundled into five categories, depending on the organizational perspective they deal with. An online survey was developed considering the groups of lean difficulties and it was then distributed to 5000 European organizations, in order to get information and perceptions about the success of lean journeys and the degree of difficulties experienced. Data were analyzed through descriptive statistics and cluster analysis, in particular using a combination of Hierarchical and K-Means methods. Results showed that respondent organizations can be clustered into two groups and, through the analysis of contingency tables, comparisons and further information about clusters composition were extracted: clusters resulted well defined in terms of degree of difficulties experienced and success of lean projects. Moreover, the existence of a relationship between firms' dimensions and success in lean implementation was verified in all clusters.

Keywords: Lean Management, Lean barriers, Hierarchical Cluster Analysis, K-means Cluster Analysis.

1. Introduction

The term Lean production was coined by Womack, Jones, and Roos (1990) in their work *The Machine that changed the world*, but Lean Management (LM) foundations lay on Toyota Production System (TPS), whose aim is the elimination of non-value adding operations. Since lean production is a multi-dimensional approach, it encompasses a large amount of management practices (just-in-time, quality systems, team-work, supplier management, etc.) in an integrated system (Shah and Ward, 2003).Hence, LM cannot be reduced to the application of a set of tools to production systems.

In the last few years, several western industries have tried to introduce this methodology (Hines et al., 2004), but most of them have not achieved the expected results. For this reason, quality programs' critical failure factors and barriers have become areas of interest for many authors. For instance, Albliwi et al. (2014) analysed common failure factors for Lean Six Sigma, while Bhasin (2012) and Jahdav (2014) focused on barriers to lean implementation. It was found that the major weaknesses attributable to western companies are characterized by a lack of concerning on the creation of a lean-oriented organizational culture (Hines et al., 2004) and the misapplication of human-related practices (Bortolotti et al., 2015).

The aim of this study is to analyse if, on the basis of the degree of difficulties experienced by the respondent organizations, it is possible to classify them and to find common characteristics within each cluster and differences between them.

In order to develop this study, the paper is organized as follows: Section 2 presents a review of relevant literature; in Section 3, the methodology adopted to assess research scope has been described. In Section 4, results are presented and discussed, while conclusive considerations are reported in Section 5.

2. Literature review

2.1 Lean barriers

Since the introduction of quality improvement initiatives harbours relevant difficulties and considering the growing interest of organizations for LM, authors dedicated their research projects to this topic. We can cite Bevilacqua et al.'s work (2017a), in which many difficulties encountered by companies undertaking a lean journey were listed: lack of innovation and information technology infrastructure, costly and time-consuming implementation, lack of a systematic and sustainable approach and difficulties to obtain bank financing, especially for Small and Medium Enterprises (SMEs). Furthermore, several academics highlighted the wide impact of lack of resources, training, education and commitment as relevant and concerning difficulties (Zhang et al., 2012; Kundu and Manohar , 2012; Jadhav et al., 2014; Halling and Wijk, 2014; Kumar and Kumar, 2014; Albliwi et al., 2015; Logaard et al., 2016; Bevilacqua et al., 2017a). More generally, we can say that an incorrect cultural approach is a trigger to the development of lean barriers: Achanga et al. (2006) found that what differentiates successful companies from on average or unsuccessful ones is the ability to create a lean-oriented culture, which sustains continuous improvement.

Even communication and knowledge sharing represent a critical failure factor, as identified by several authors (Bevilacqua et al., 2017a; Albliwi et al., 2015; Achanga et al., 2006). Moreover, personnel commitment can be achieved providing the adequate support by top management and rewards to recognize the participation in lean projects (Zhang et al., 2012).

After this brief summary of the more relevant barriers at lean implementation, a further consideration is needed: analysing lean difficulties in general might result garbling, so five bundles of barriers depending on the organizational perspective were identified. In particular, we considered as strategic barriers those critical issues concerning organizational decision-making process and planning for future actions. Lack of financial, time and human resources to dedicate to LM implementation were considered as economic difficulties, while relationships and involvement along the whole supply chain were referred to as Supply Chain Integration (SCI) barriers. Managers' support and personnel cooperation can be grouped as human difficulties while the degree of lean-oriented mindset, responsiveness and helpfulness between the whole staff represent cultural barriers.

3. Methodology

The questionnaire is organized in two sections. The first one regards general information about each company and the environment in which it operates. Specifically, it begins with a filter-question, in order to assure that all the respondent organizations had at least started a lean project. Moreover, the working position of the respondent, firm dimension in terms of number of employees, the industrial sector and the percentage of demand variability are requested. Furthermore, the respondent is required to indicate, according to his/her own perception, which is the percentage of successful lean projects already implemented in the organization.

Data analysis was performed using SPSS, an IBM tool for data mining, text analytics, and statistical analysis. In order to provide an overview of sample composition, a descriptive statistics analysis of questions belonging to section 1 was carried out.

The second section, instead, asks an evaluation of difficulties encountered during a journey: issues identified in extant literature are reported as single items and organized according to the previously mentioned classification within strategic, economic, SCI, human and cultural barriers. A five-point Likert scale is used in order to quantify whether each item represents a relevant barrier to lean implementation: a score of 1 is attributed if the item is not considered critical by the respondent, while a score of 5 evidences extreme criticality of the corresponding element. A complete list of the items is reported in Appendix A. The survey was developed through an apposite online module and data were collected thanks to the support of lean institutes and lean consultant companies.

A Confirmatory Factor Analysis (CFA) was carried out in order to assess whether the hypothesized relations between items and the corresponding latent constructs representing lean barriers' bundles were statistically significant. Then, a cluster analysis was performed on second section's items, with the aim of identifying groups of respondent organizations facing the same level of difficulties.

Since the number of clusters was not fixed, data were analysed through a multivariate analysis technique: firstly, a hierarchical cluster analysis was applied, using Ward's method and computing distances with Squared Euclidean algorithm. Through the elbow rule, the more appropriate number of clusters was defined. Hence, K-Means method was applied to perform a further cluster analysis using the fixed number of clusters determined during the previous step. In order to evaluate whether the groups were well defined and if there was a significant difference in the level of barriers experienced between the clusters, a Mann-Whitney U test was executed. Finally, a descriptive statistics analysis was carried out in order to get information and compare the characteristics of the identified clusters.

4. Key findings and discussion

4.1 Descriptive statistics and data validation

The questionnaire was addressed to firms based in Europe and data were collected through the support of lean institutes and lean consultant companies. 171 completed survey, out of the 5000 distributed, were returned. However, according to the recommendations provided by Burgess-Limerick et al. (1998), the sample was greater than 100 and, even though the response rate was lower than 20%, reliability was assessed: indeed, firstly, standardized regression weights of each construct were reviewed and three items (C1.A6, C1.D1 and C1.E7) were dropped, as they did not respect the recommended 0.5 threshold (Hair et al., 2006). Then, Cronbach's alpha was calculated in order to establish internal consistency reliability: the recommended value of 0.7 was respected by all constructs. Similarly, even Average Variance Extracted and Construct Reliability were assessed, as their values were respectively above 0.5 and 0.6 for all the constructs.

In Appendix B, latent constructs, items, factor loadings and the corresponding index are reported.

The interviewed sample resulted heterogeneous; the addressees were those firms belonging to all fields of sector C according to the "Statistical Classification of Economic Activities in the European Community, Rev. 2" (2008). Respondent organizations are based in 19 different European countries: 60% of the compiled questionnaires were returned from Italian companies, while 18% belongs to firms located in Spain, United Kingdom and Germany. The remaining respondent companies are situated in Slovenia, Romania, Slovakia, Russia, France, Netherlands, Czech Republic, Hungary, Norway, Portugal, Lithuania, Poland, Serbia, Switzerland and Denmark. Furthermore, 45.03% of the 171 respondents belongs to electrical and mechanical machinery and equipment sector, 8.77% to food and beverages, 8.19% to textile, leather, and clothes, while a 7.60% dedicate to transport products. Pharmaceutical and chemical sectors respectively represent the 2.34% and 1.75% of the sample. The remaining 26.32% belongs to unclassified sectors. Concerning the number of employees, the 61.40% of firms employ more than 250 people, in 21.64% there are between 50 and 250 workers, between 50 and 10 in the 8.77% of the companies while the remaining 8.19% employs less than 10 workers. Moreover, the 57.31% of the firms has an annual turnover of more than 50,000,000 €, the 28.65% between 10 and 50 million, the 10.53% between 2 and 10 million and the remaining 3.51% less than 2,000,000 €.

The majority of respondents (31.58%) is employed as a lean specialist, followed by production control manager (18.71%), president/COO/plant manager (18.13%), process engineer (12.28%) and member of product development team (5.85%). The remaining percentage is divided into other professions.

In order to test whether the distribution of the provided answer was approximately normal, skewness was calculated for all items. Results can be considered acceptable, as values are between -2 and +2 (George & Mallery, 2010).

4.2 Cluster analysis

After having analysed the composition of the sample, a cluster analysis was performed, considering all variables of section 2 (lean barriers) which passed the validation step as clustering attributes for the cases. In order to choose the right number of clusters, a hierarchical algorithm with Ward's method and squared Euclidean distances was launched. From the analysis of the agglomerative schedule, obtained from this method through the elbow rule, it was found that a classification into 2 clusters was desirable. Hence, a K-Means cluster analysis considering 2 groups was performed. In order to increase the relevance of this clustering, the Mann-Whitney U test was executed: results proved that groups were well defined as there was a significant difference degree of barriers experienced between the clusters (Appendix C).

After this procedure, cluster 1 resulted to be composed of 56 respondents, while cluster 2 contained the remaining 115. The first analysis conducted on the results consists of comparing the average value obtained by each cluster for each difficulty identified in Section 2: the mean value of each factor is calculated determining the mean value of each item and averaging out the obtained values.

As we can note from results reported in Table 1, organizations included in cluster 2 present a low score in all bundles of barriers, hence we can say that they have to face fewer difficulties than other firms do.

Table 1 Barriers mean value comparison between clusters

Cluster	Nr. of firms	Strategic	Economic	SCI	Human	Cultural
1	56	3,325	3,782	4,202	3,848	3,911
2	115	1,986	1,979	3,544	2,024	2,210

On the contrary, cluster 1 members have to deal with a high level of barriers during their lean journey: indeed, organizations belonging to this group present a higher average score for every area. These trends can be also observed in Figure 1. Specifically, we can see that SCI barriers are the most critical for all the identified clusters. The relevant barriers to be faced identified along the supply chain may highlight the attitude to concentrate in implementing LM internally, experiencing difficulties in working with non-lean suppliers or customers. We can also note that cultural issues achieve the second higher score in all clusters. This fact underlines that, in implementing LM, a deep cultural change is required. Indeed, western companies are not familiar with teamwork and training projects, hence a marked cultural effort is required to concentrate on educational and cooperative aspects.

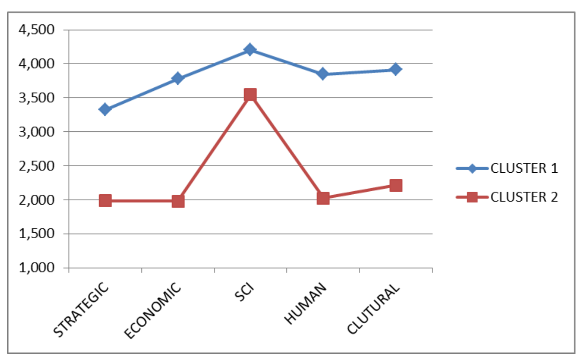

Figure 1 Mean values of difficulties per cluster

4.3 Cluster profile: contingency tables

Further analysis was conducted through contingency tables in order to mine more precise information about clusters' composition. In particular, these statistics tables aim at correlating clusters to the questions of section 1. Results reported in Table 2 show a comparison between clusters in terms of number of employees. Cluster 1 is mainly composed of SMEs (32 out of 56), while clusters 2 presents a higher percentage of large enterprises. Indeed, 81 out of 115, hence about 70% of the organizations belonging to this cluster, classified themselves as large. Analog considerations can be made relatively to turnover. Even though the percentages are slightly different, the trend is similar to the former one.

From these results, we can say that firms dimension has a relevant impact on the degree of barriers experienced, evidencing a significance level lower than the threshold of 0.05.

Table 2 Contingency table: clusters vs number of employees

	CLUSTER		
	1	**2**	**TOTAL**
SMEs	32 (57,2%)	34 (29,6%)	66 (38,6%)
LARGE	24 (42,8%)	81 (70,4%)	105 (61,4%)
TOTAL	56 (100,0%)	115 (100,0%)	171 (100,0%)
Chi-Square	**χ2**	14,157	
	Sig	0,003	

During a lean journey, indeed, the implementation of certain practices require a deep effort connected to supplier and employees, in addition to high level of quality and production efficiency (Bevilacqua et al., 2017b). Generally, small firms have fewer resources if compared to larger firms (Kennedy and Hyland, 2003): this fact justifies the low level of barriers encountered by members of cluster 2, mainly composed of large companies.

Table 3 Contingency table: clusters vs percentage of successfully developed lean project

% OF SUCCESS	**CLUSTER**		**TOTAL**
	1	**2**	
0%	1 (1,8%)	1 (0,9%)	2 (1,2%)
0% - 20%	33 (58,9%)	13 (11,3%)	46 (26,9%)
20% - 50%	14 (25,0%)	29 (25,2%)	43 (25,1%)
50% - 90%	4 (7,1%)	54 (47,0%)	58 (33,9%)
> 90%	4 (7,1%)	18 (15,7%)	22 (12,9%)
TOTAL	56	115	171
Chi-Square	**χ2**	51,744	
	Sig	0,000	

As previously mentioned, one of the questions of the first section of the questionnaire regarded the percentage of lean projects already developed in respondent organizations that are considered successful, according to respondent perception. Table 3 reports resulting answers and classify them in terms of clusters, highlighting that the perception of success has a significant impact on cluster definition ($\chi 2=51{,}744$, $p<0.005$). We can see that two out of 171 respondent perceive that they have not yet implemented successful lean projects, while 22 companies have managed to achieve almost the totality of success. Matching these results with those reported in figure 2, we can reasonably affirm that the degree of lean barriers experienced is inversely proportional to the percentage of successful projects implemented. Considering a score exceeding 50% as a positive result, more than the 60% of firms belonging to cluster 2 successfully implemented the attempted lean projects. On the contrary, just a 14% of cluster 1 members reached similar results. This result could have been predicted considering the degree of difficulties experienced by respondent organizations. These findings are in line with some aspects evidenced in previous studies. For instance, Achanga et al. (2006) found that most SMEs are strategically hindered by a lack of management expertise, that leads to unsuccessful attempts in implementing lean. Furthermore, Bevilacqua et al. (2017a) highlighted that SMEs may incur in more difficulties in obtaining financing from banks than large companies. Hence, lack of resources, skills, and expertise can be considered as the main causes of the previously mentioned differences in lean success, as it was shown that cluster 1 was mainly composed of SMEs and experienced the greater level of difficulties. Top management commitment and communication were also considered as critical issues (Achanga et al., 2006; Bortolotti et al., 2015; Bevilacqua et al., 2017a) and it was found that SMEs are rarely aware of these aspects (Bevilacqua et al., 2017a). Further training and education on these aspects represent key practices in order to improve current performances. Moreover, lean information management should be introduced in lean companies, as it was found to improve overall performance (Bevilacqua et al., 2015).

Table 4 Contingency table: cluster vs industrial sector. A: chemical products; B: electrical and mechanical machinery and equipment; C: food & beverages products; D: pharmaceutical products; E: textile, leather & clothes products; F: transport products; G: unclassified sector.

	CLUSTER		
INDUSTRIAL SECTOR	**1**	**2**	**TOTAL**
A	2 (3,6%)	1 (0,9%)	3 (1,8%)
B	26 (46,4%)	51 (44,3%)	77 (45,0%)
C	2 (3,6%)	13 (11,3%)	15 (8,8%)
D	0	4	4

	(0,0%)	(3,5%)	(2,3%)
E	7 (12,5%)	7 (6,1%)	14 (8,2%)
F	3 (5,4%)	10 (8,7%)	13 (7,6%)
G	16 (28,6%)	29 (25,2%)	45 (26,3%)
TOTAL	56	115	171
Chi-Square	**χ2**	8,723	
	Sig	0,190	

Table 4 presents clusters' composition in terms of industrial sectors. We can see that 45% of interviewed sample produce electrical and mechanical machinery and equipment. About 26% of the companies belong to unclassified sectors, while the remaining enterprises dedicate to the production of chemical, pharmaceutical, textile, transport and alimentary products. Their distribution does not characterize group composition, as it is quite homogeneous within clusters and the Chi-Square test shows a significance level higher than 0,05. Hence, we can say that this dimension is not influent in differentiating the two clusters in terms of difficulties experienced.

The majority of respondents affirmed that demand variability of the corresponding sector is low: indeed, about 87% of the responding firms scored demand variability lower than 50%, and 76% of them presented a value lower than 20% (see Table 5). According to the Chi-Square test, even this variable has an impact on cluster definition ($\chi 2$=11,011, p=0,026). Naylor et al. (1999) affirmed that lean production tends to reduce demand variation by optimizing, simplifying, and streamlining the supply chain. Analysing Table 5, we can observe that scores of cluster 2, that includes the majority of top performant enterprises, are in line with this view.

Table 5 Contingency table: clusters vs demand variability

	CLUSTER		
% OF VARIABILITY	**1**	**2**	**TOTAL**
0%	8 (14,3%)	26 (22,6%)	34 (19,9%)
0%-20%	41 (73,2%)	55 (47,8%)	96 (56,1%)
20%-50%	4 (7,1%)	15 (13,0%)	19 (11,1%)
50%-90%	0 (0,0%)	5 (4,3%)	5 (2,9%)
> 90%	3 (5,4%)	14 (12,2%)	17 (10,0%)
TOTAL	56	115	171
Chi-Square	**χ2**	11,011	
	Sig	0,026	

However, even members of cluster 1– hence the low performer- present a variability level quite low: indeed, 53 companies out of 56 affirmed to have a percentage of demand variability lower than 50%. This aspect majorly remarks the virtuous behaviour of organizations belonging to the former group. On similar demand variability, these enterprises manage to obtain better results and to face better with difficulties. Comparing firms having a demand variability higher than 50%, we can see that only 3 out of the 56 (5,3%) components of cluster 1 recognize a high variability, against a 16,5% of cluster 2 members: despite a consistent demand variability, the latter manage to achieve better results in terms of barriers experienced.

5. Conclusion

LM implementation entails a series of difficulties to face, as it involves the modification of the complete production asset. Indeed, strategic, economic, SCI, human and cultural fields are touched by improvement programs. The aim of this work is to cluster a set of firms according to the level of barriers experienced during lean projects implementation. Through an appositely developed questionnaire, indeed, companies were asked to evaluate the degree of strategic, economic, SCI, human end cultural difficulties they have to face along their lean journeys. A cluster analysis was conducted in order to identify differences and similarities among respondent organizations. Our findings highlight that the 171 interviewed enterprises can be clustered into two groups, internally homogeneous in terms of difficulties experienced and percentage of successful lean projects implementation.

These results will allow managers to understand better the necessity of concentrating on reducing the more significant difficulties, according to the belonging cluster, in order to improve their performances. Moreover, this analysis can be considered by non-lean enterprises who want to undertake a lean journey: knowing their dimension and demand variability, they could hypothesize to belong to one of the clusters and, in implementing LM, they could concentrate on the more critical aspects.

Despite the usefulness of this research, it should be noted that an enlargement of sample dimension per industrial sector is desirable, in order to increase results' relevance.

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Appendix A: Description of items belonging to Section 2 of the questionnaire

	Item	Item description
STRATEGIC BARRIERS	**C1.A1**	Top managements are aware of the need for Lean implementation.
	C1.A2	The Project Goal is clear to all the staff.
	C1.A3	Top management knows how to get started.
	C1.A4	The staff has a clear vision of the project and a future plan.
	C1.A5	Process and division where starting the lean program has been selected with specific criteria.
	C1.A6	Lean programs are perfectly in line with organization bonus, rewards or incentives systems.
ECONOMIC BARRIERS	**C1.B1**	Financial availability for the initial employees' training course.
	C1.B3	Financial availability for the initial top managers' training course.
	C1.B7	Financial availability to have outside experts for successfully shifting to lean.
	C1.B5	Financial availability to invest in lean program.
	C1.B6	Time availability to invest in lean program.
	C1.B2	Time availability for the initial employees' training course.
	C1.B4	Time availability for the initial top managers' training course.
	C1.B8	Availability of human resource to invest in lean program.
	C1.B9	Availability of technical resource to invest in lean program.
SUPPLY CHAIN INTEGRATION BARRIERS	**C1.C1**	Ease in involving customer in lean projects because of consistent and clear communication with them.
	C1.C2	Ease in involving supplier in lean projects because the majority of them are close to the company.
	C1.C3	Ease in involving suppliers in lean projects because of long-standing relationship with them.
	C1.C4	Ease in involving suppliers in lean projects because of consistent and clear communication with them.
	C1.C5	Ease in involving suppliers in lean projects because they see incentive in adopting the JIT approach.
	C1.C6	Ease in involving the entire supply chain because of Partnership or closer relations with carriers and logistic

		providers.
HUMAN BARRIERS	**C1.D1**	Top management support in implementing lean projects.
	C1.D2	Shop floor personnel support in implementing lean projects.
	C1.D3	Employees are responsive to participate to productivity improvement project and they have no fear of staff reduction.
	C1.D4	Employees are responsive to participate to productivity improvement project because interested in learning something new.
	C1.D5	Lean project have committed leadership.
CULTURAL BARRIERS	**C1.E1**	Cross Functional group (people from various department and levels within the organization) have been created.
	C1.E2	Personnel are responsive to participate to training course in order to receive at least Basic knowledge and skills about lean concepts.
	C1.E3	Top managers are responsive to participate to training course in order to receive at least Basic knowledge and skills about lean concepts.
	C1.E4	Outside experts are well accepted by personnel in the start-up phase of the lean project.
	C1.E5	A training roadmap about lean concepts has been set up.
	C1.E6	Low education of employment does not represent a barrier in implementing lean.

Appendix B: Factor loadings and reliability analysis of items in questionnaire's section 2.

	Item	Factor Loading	AVE	Construct Reliability	Cronbach's Alpha
STRATEGIC	C1.A1	0,844	0,629	0,893	0,881
	C1.A2	0,848			
	C1.A3	0,866			
	C1.A4	0,79			
	C1.A5	0,584			
ECONOMIC	C1.B1	0,792	0,681	0,950	0,954
	C1.B2	0,923			
	C1.B3	0,799			
	C1.B4	0,899			
	C1.B5	0,838			
	C1.B6	0,873			
	C1.B7	0,701			
	C1.B8	0,799			
	C1.B9	0,781			
SCI	C1.C1	0,535	0,723	0,938	0,935
	C1.C2	0,93			
	C1.C3	0,944			
	C1.C4	0,949			
	C1.C5	0,869			
	C1.C6	0,801			
HUMAN	C1.D2	0,777	0,698	0,900	0,906
	C1.D3	0,948			
	C1.D4	0,936			
	C1.D5	0,642			
CULTURAL	C1.E1	0,738	0,550	0,878	0,871
	C1.E2	0,847			
	C1.E3	0,733			
	C1.E4	0,713			
	C1.E5	0,829			
	C1.E6	0,553			

Appendix C: Mean difference of barriers in the two clusters

Item	Mann-Whitney U test	Sig.
C1.A1	1453,500	0,000
C1.A2	1174,500	0,000
C1.A4	1256,500	0,000
C1.A3	1031,000	0,000
C1.A5	1131,500	0,000
C1.B1	765,500	0,000
C1.B3	629,500	0,000
C1.B7	1115,000	0,000
C1.B5	565,500	0,000
C1.B6	491,500	0,000
C1.B2	563,000	0,000
C1.B4	724,500	0,000
C1.B8	807,000	0,000
C1.B9	951,000	0,000
C1.C1	1642,000	0,000
C1.C2	1770,500	0,000
C1.C3	1831,000	0,000
C1.C4	2097,500	0,000
C1.C5	2071,500	0,000
C1.C6	2304,000	0,002
C1.D2	479,000	0,000
C1.D3	671,000	0,000
C1.D4	848,000	0,000
C1.D5	730,500	0,000
C1.E1	810,500	0,000
C1.E2	476,000	0,000
C1.E3	1298,500	0,000
C1.E4	1101,500	0,000
C1.E5	615,500	0,000
C1.E6	1506,500	0,000