Assessing Project Progress Planning using Control Diagrams and Neural Network Prediction for Shipbuilding Projects in an Ecuadorian Shipyard

Gerardo Mena Caceres[a]
Project Management Office, MSc. Global Production Engineering & Management,
Global Production Engineering & Management, AV 8ANO, Guayaquil, Ecuador

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Abstract: The planning and scheduling of new shipbuilding projects, as in other engineering disciplines require a certain degree of experience and knowledge in order to provide progress planning of feasible works to achieve the goals of the project and the managerial expectation. As is mentioned, although having experience is necessary; according to current technologies, the use of data analysis and the certainty that in the medium-term future artificial intelligence will be used in decision-making, it is necessary that not only manufacturing be according to the approaches of industry 4.0 but also, project management from its start-up phase to closure uses mechanisms for continuous improvement in a more successful way. This case study focuses on the data analysis of planned and executed projects to estimate acceptable percentages of periodic progress of projects using parameters of reliability engineering and neural network model from ISPP IBM software, in such a way that the planning can be in accordance with the shipyard behaviour.

1 INTRODUCTION

Projects of any kind comprise different stages of development, which go through initiation and planning, execution, monitoring and control and closure, and also have as parameters or "natural" constraints the scope, time, quality, and cost (Project Management Institute, 2017). However, at the time of preparing the project, it's planning and schedule, it is based more on the experience of the project manager rather than on data recorded by the companies, this experience makes this activity inherent to whoever owns it, causing Project Managers (PMs) to estimate project base line empirically or simply to what a planning program says without examining data based on similar previous projects or business behavior even when they already exist.

Scheduling and progress planning are essential in order to understand the base line of the project and in order to figure out the managers' intentions, that in the end combined with the balance of the project will determine if it was successful or not.

This document focuses on showing the current importance for project managers the data analysis for planning and thus making estimations or predictions based on an analysis of data behavior, for progressive project planning in a way more accurate, using the registered data in the case of a specific company dedicated to the new shipbuilding projects in Ecuador.

2 PROBLEM STATEMENT

Projects are characterized because they have a time limit, that is, they have a beginning and a specific duration (Lledó, Rivarola, Mecaru, & Cucchi D, 2006) given this, it requires an effort that is definitely not constant and varies according to the type of project, its scope, and available resources, also considering the natural constraints mentioned above. The shipbuilding industry in Ecuador is not too much developed in terms of technology, innovation and manufacturing techniques, so, generally speaking these kinds of business needs to be assessed according to the actual situation seeing their own

[a] https://orcid.org/0000-0002-9169-6765

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constraints, strengths and weaknesses in order to establish the best solution for them.

To execute any kind of project, the initial outline or route to follow is required, so that those involved in its development have full knowledge of the expected scheduled progress, this is obtained through planning, which can be developed in some existing software (Excel, Project, etc.), but how could we determine if the planned and desired progress is in accordance with the business reality? This question leads us to ask whether the experience alone guarantees adequate planning and scheduling of activities, and whether it is ultimately feasible or not that the goals set are met according to a plan.

3 GENERAL CONCEPTS

3.1 Variability

Every system has variability, it is independently of what kind of system it represents and the variability is determined by the standard deviation of the data in relation to its arithmetic mean (average), which allows establishing in addition to the variance, the form, or dispersion of the existing data. Variability should not be seen as a problem in systems, as it can be good or bad depending on the group or situation being analyzed (Hoop & Spearman, 2008).

3.2 Standard Deviation

It is defined as the square root of the variance (Hines & Montgomery, 2004), the standard deviation is the measure of dispersion most used to determine the variability of a system.

3.3 Project Planning and Scheduling

Planning and scheduling are different but related to them. We can say that scheduling is the lower level of the planning, it focuses on the action that people need to do in specific time, and planning involves the tasks that the project needs to occur and how to do.

3.4 Project Progress

Although projects, like any process, require keep in mind the integrity of the components of the system, the development of this work will take into consideration the planning in terms of percentage that include all the activities entailed to complete the shipbuilding project.

In other words, it is related to earned value index which is commonly used to assess planning and progress for the projects.

3.5 Statistical Control

Statistical control of processes through the use of troubleshooting tools, allows, among other things, to establish whether a system is under control, the level of variability of the system, which allows the application of continuous improvement and the correction of possible process “failures”.

4 METHODOLOGY AND SOLUTION DEVELOPMENT

To analyze the feasibility of data-driven planning, it is necessary to collect existing data which is based on reports generated by each project manager and/or those presented by the functional units of a company. From them, the following work methodology will be applied:

- Sort the data according to each project executed and planned.
- Calculate the planned and executed monthly progress of each project, as a differential.
- Calculate the standard deviation, the arithmetic mean, variance coefficient.
- Perform statistical control of the process by applying control diagrams
- Analyze and make estimates of minimum times and average percentages based on data from control theory.
- Apply neural network prediction on the sorted data
- Analysis of the results.

It is noticeable that shipyards, like other companies, collect certain data according to their policy, however, the technical staff should make recommendations about the kinds of data that are needed.

4.1 Input Data

4.1.1 Accumulated Progress Data by Project

Before making any kind of calculation, it is required to know if any technological change has been implemented, if the process has changed or improved, and look for the factors that may have altered the current state of the company which can be translated into variability. In the event that the system has not been implemented or adjusted to new technologies and methodologies, it is recommended to use as much data as possible, and in case new technologies have been implemented, the evaluation should be based on this new business reality.

In the present case, since the company has not carried out any implementation, the data collected comes from all the projects in which the shipyard's own workforce has been required, which uses the same construction, control, and similar process methodologies.

The data shown in Table 1 is an extract and it represents the percentages of the accumulated progress planned (PP) and executed (EP) by the different projects, in this particular case, the data corresponds for the monthly progress (T). However, the data collection will depend on the policy implemented, if it exists.

For the study of the present case, ten executed projects during the last 4 years have been considered, it is worth mentioning that, although they are not all projects executed within the shipyard, these projects have a register.

Table 1: Example of cumulative progress data planned.

T	PP2,1	PP2,2	PP2,3	PP2,4	PP2,5	PP2,6
0	0%	0%	0%	0%	0%	0%
1	23%	23%	23%	23%	23%	23%
2	48%	48%	48%	48%	48%	48%
3	59%	59%	59%	59%	59%	59%
4	69%	69%	69%	69%	69%	69%
5	85%	80%	80%	80%	80%	80%
6	100%	90%	84%	84%	84%	84%
7		100%	93%	88%	88%	88%
8			100%	94%	92%	92%
9				100%	96%	94%
10					100%	97%
11						100%

Within the data observed for this case study, the different projects have been differentiated by using generic acronyms which have data on project planning, execution, and re-planning that can show the changes that the projects have had since their initial planning (PPi, 1), and until the last adjustment made (PPi, j), this means that in many cases the execution of the project (EPi) is equal to the latest version of the planning readjustment. For instance, the project number one would be P1, the first planning for this project will be represent by PP1,1 at the end if the project number one has four changes in the planning the identification will be PP1,4. This mechanism is used to identify all the projects. On the other hand, the executed projects are identified just for one number, for the same given example the execution for the project number one will be EP1.

Likewise, it includes planned projects that are in execution (PPAi, j) with the same re-planning characteristics (if they exist), and the current execution that they carry (EPAi). This variable differentiation allows to establish initially:

- There is new planning of the projects since there are deviations in the baseline.
- The baseline has not been kept constant for any of the existing projects.
- None of the planning carried out by the project managers and their teams has been reached or, saying in other way, they have not been carried out correctly.
- The production behavior of the shipyard has not been included during the planning phase.

This can be evidenced if the different plans are drawn up, where the initially planned progress curve can be verified and how the actual execution of the project was, which gives us the basis for raising the need of this study.

It is worth mentioning that, as in any project and the stages of execution that each maintains, the theoretically progressive proposed progress obeys a Gaussian way as shown in Figure 1, therefore, it would be expected that the plans have a similar relationship where the effort is gradual both at the beginning and at the end so that the project does not have excessive or constant costs throughout its life-cycle.

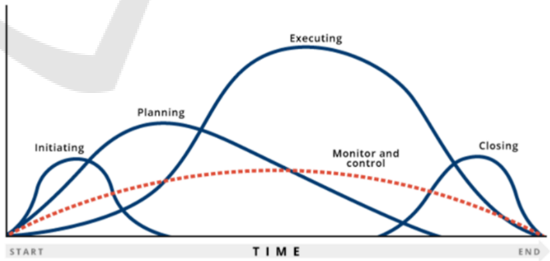

Figure 1: Overlap between Project Management's Processes[1].

The data collection is carried out by each project manager and wrote down in excel document provided by the project office. Nevertheless, each project manager estimates the progress according to their perspective. Shipbuilding is structured by different

[1] https://voices.berkeley.edu/business/deconstructing-project-management-process

components or disciplines: welding, auxiliary systems, navigation, electrical and communication system, carpentry, propulsion and steering system. The data shown in this document is the summary of all those shipbuilding components and the weight or significance of each of them are not standardized. Assign or determine a weight of each component is a pending task not only for the Ecuadorian shipyards (Arena, Birkler, Schank, & Riposo, 2005), but is a task that production department or strategic one should conduct.

4.1.2 Project Monthly Progress

To calculate the planned and executed monthly progress of the projects, it is carried out simply by subtracting terms, that is, these data are the differential of those established in Table 1.

$$\Delta PPn = \Delta PPi,j = PPi,j{+}1 - PPi,j \qquad (1)$$

Table 2: Example of progress data planned and executed by projects.

PP2,1	PP2,2	PP2,3	PP2,4	PP2,5	PP2,6
23,0%	23,0%	23,0%	23,0%	23,0%	23,0%
25,0%	25,0%	25,0%	25,0%	25,0%	25,0%
10,5%	10,5%	10,5%	10,5%	10,5%	10,5%
10,5%	10,5%	10,5%	10,5%	10,5%	10,5%
16,0%	10,5%	10,5%	10,5%	10,5%	10,5%
15,0%	10,5%	4,00%	4,00%	4,00%	4,00%
	10,0%	9,50%	4,00%	4,00%	4,00%
		7,00%	6,50%	4,00%	4,00%
			6,00%	4,00%	2,83%
				4,50%	2,83%
					2,84%

Remember that there must be N-1 elements as data.

4.2 Statistical Control of the Process

Table 3: Example of dispersion measurement calculation results.

	Mean	Var.	Std. Dev.	Coef. Var.	Std.Err.
PP1	0,1075	0,00202	0,0449	41,823	0,0159
EP1	0,1000	0,00130	0,0361	36,156	0,0114
PP2,1	0,1666	0,00377	0,0614	36,872	0,0251
PP2,2	0,1428	0,00444	0,0666	46,645	0,0252
PP2,3	0,1250	0,00557	0,0746	59,713	0,0264
PP2,4	0,1111	0,00604	0,0778	69,995	0,0259
PP2,5	0,1000	0,00632	0,0795	79,512	0,0251

The calculation of the dispersion´s measures mentioned above, although they can be done “manually”, for this work the same computer tool that will be used to estimate the results is used with the following data as a representation:

The presentation of the dispersion measurement of the other variables are presented in the annex and the control diagrams have the same structure as in the Figure 2.

From the control diagrams, it can be established whether the process was under control or not, and because the projects presented have had a certain degree of re-planning, it will be possible to show the changes that the standard deviation, mean and the coefficient of variability has one with respect to another.

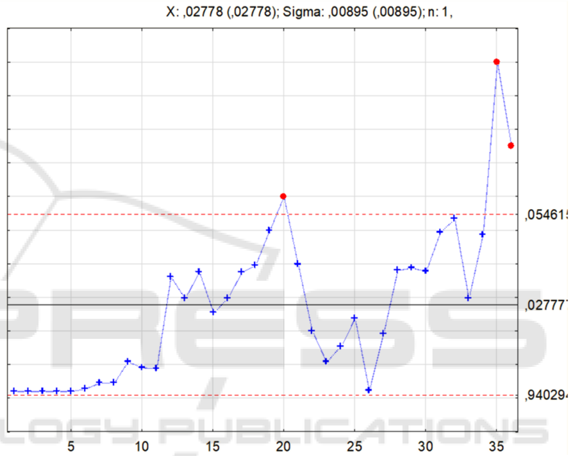

Figure 2: Control Diagram - variable EP3.

As can be seen in figure 2 for the case of the variable EP3 that represents the execution of project # 3, it can be said that the process was under control, however, as part of the project management tasks, it should be examined why three points were considered "out of control", the fact that the points are outside the limits of the process, although they give the alert that something happened, will not always mean that something was "wrong", and as was mentioned it is a task of management of projects that must be included in the lessons learned with their respective analyzes that will allow continuous improvement of the process.

As can be seen in Table 3, different coefficients of variability are given for each of the parameters and it can be seen that the variable EP5 has the highest value, even when the variability of initial planning is less, which translates into that not necessarily the entire construction processes ended with a low variability due to the lengthening of the execution period, but the average percentage of execution was less than planning, this, in turn, varies the control limits.

4.3 Analysis of Variables and Estimation of Percentages of Progress

Among the analysis, the first point is the presentation of the frequencies, which will allow establishing the progress values within a "normal" working range of the company, for example, in the shipyard, it can be seen that the majority of the time used an effort of up to 9.6% more frequently, so the values greater than 10% per month are not realistic.

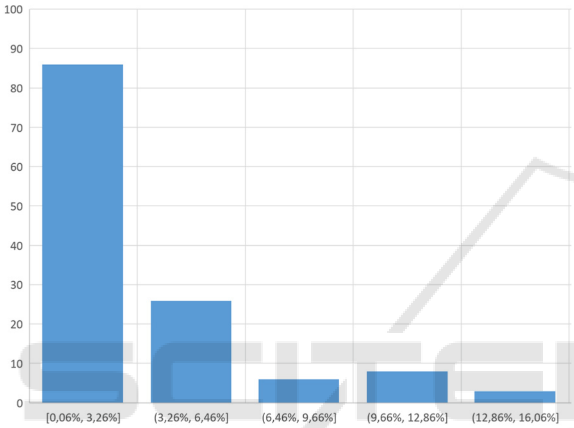

Figure 3: Actual direct frequency diagram.

The first action to be taken is to define those variables that will be included for the calculation of the predictions, for a better understanding by way of example, the following idea can be proposed:

- If the project is intended to be executed in a planned time T, the projects to be chosen must have at least T + 1 amount of data.
- The data of projects that are in execution, they can be considered for the estimation as well as their planning as long as the previous condition is met.
- The data pertaining to the actual execution completed for each project will be selected, that is, EPi.

Choosing the data is a vitally important task since the regressions to calculate the number of X approximations require the same amount of data as the base, that is, it uses data one by one.

On the other hand, there is information regarding project management concepts, such as the use of EV which is closely linked to the costs and resources used, although this is the standard methodology for project evaluation, it is worth mentioning that the percentages of Execution of shipbuilding projects presented here are carried out with the joint evaluation of the project management component and the execution component (manufacturing).

The proposed methodology will be applied to two similar shipbuilding projects that have different schedules, different project managers, and different execution times, showing the results of the proposed data analysis numerically and graphically.

4.3.1 Estimated Monthly Percentages of Progress

If we apply the neural network method or any other existing tool, such as the tree regression method or any other regression model, it will show us different results. It is clear that the examination of these results is crucial to know if they are adequate or not.

When neural networks are applied, the output data is based on "weight" values before continuing to its next phase of internal analysis, so the larger the data for the dependent variables, the approximation and mean error will decrease, however, as mentioned, they act on dependent and independent variables or factors, in this particular case and since the percentages recorded are total values and there is no data on the partial values that compose it, it will be assumed that the dependent variables are the schedules of the current projects to evaluate, and the dependents will be the data recorded as actual or executed progress of the projects.

The neural network based on Multi-layer perceptron (MLP) was used to develop this case, having a maximum number of hidden layer 50 and "batch" training. Batch training is used in case where the dataset is small, which is this case.

Applying neural networks in both projects and superimposed on the total progress curves we will have the following results:

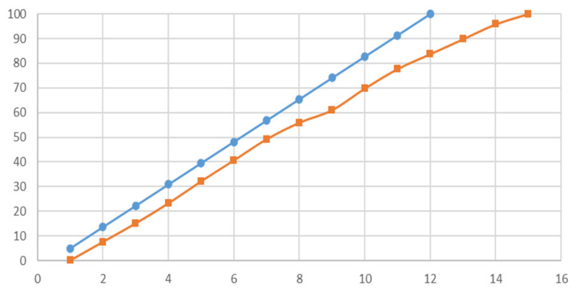

Figure 4: Accumulated Progress Curve PPA7.2.

The orange line represents the MLP result, and the blue one the baseline planned by the project manager.

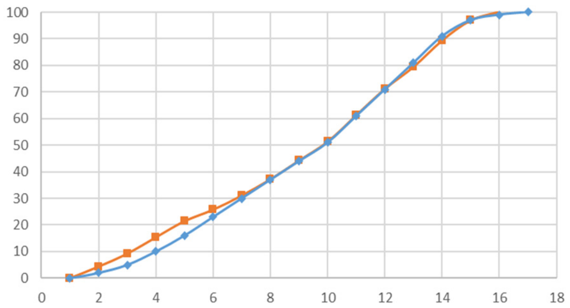

Figure 5: Accumulated Progress Curve PPA8.1.

On the other hand, although the accumulated progress curves are important, the monthly progress effort curves must be analyzed, this will give information to validate or not the presented approach, to easily observe the result, the aforementioned control charts are shown where the curves overlap and the confidence intervals can be seen.

Confidence intervals are determined by calculating the mean and standard deviation. Figure 6 and 7 show the confidence interval, the mean, and the respective curves for both cases.

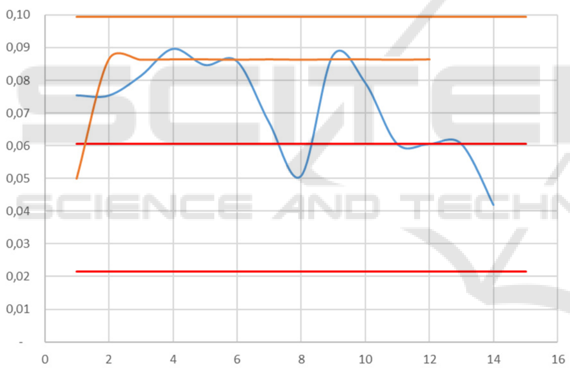

Figure 6: Monthly Progress Curve PPA7.2.

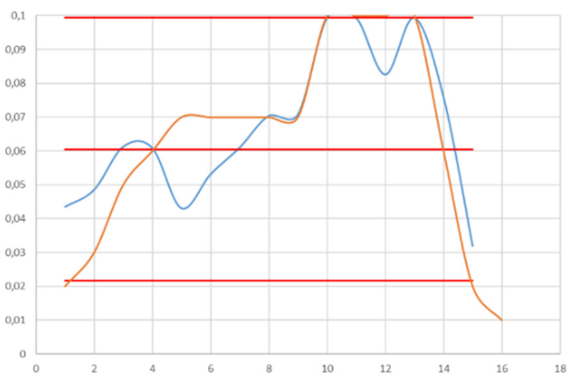

Figure 7: Monthly Progress Curve PPA8.1.

Maintaining the reference of the proposed colors, in both figures, it can be seen how the estimated values that apply the neural network present a low effort at the beginning and later reach their peak to decrease, and in the same way, in the first project despite Being within the control limits, the effort is constant for 80% of the time and, according to the forecast, it cannot be completed on time.

On the other hand, in the second graph, we see that the trends are similar, and the project can even be completed before the planned time and be within the confidence limits.

4 CONCLUSIONS

While some data exists in the shipyard, they are not used by project managers and the project office for analysis, it can be verified because the projects show multiple rescheduling.

Statistical control supports the decision-making because it can show an "apparent effort" and if production personnel is applying the needed effort to achieve the objective.

The next stage is to examine the shipbuilding activities and processes such as: welding, piping, electrical, equipment, carpentry and painting process, which make up the total percentages used in this document in order to determine the critical process and the significances for the projects.

Since the progress percentages are directly related to the work effort; translated into the use of human resources, this form of planning will allow a better distribution of the shipyard's resources.

Neural network prediction can be applied in order to support the initial baseline estimation.

Using control parameters and reliability engineering concepts is useful in determining the best lead percentage distribution options.

Analyzing business behavior patterns are necessary to improve decision-making in the case of the shipyard in order to carry out projects with short completion times (6-8 months) of complexities similar to those already executed, the shipyard's production department should increase its capacity and capability, for this, it is necessary to analyze the productivity parameters of the shipyard and its KPIs.

If the shipyard applies data analysis, problems like delays or incorrect planning could be corrected.

From personal experience and knowledge, only one shipyard in Ecuador uses a project management methodology and records data, so this document can help shipyards or dry docks in Ecuador to realize the importance of data collection and analysis.

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APPENDIX

Table 4: Dispersion Measurement Calculation Results.

Proj.	Mean	Variance	Std.Dev.	Coef.Var.	Std.Err.
PP1	0,107500	0,002021	0,044960	41,8235	0,015896
EP1	0,100000	0,001307	0,036157	36,1566	0,011434
PP2,1	0,166667	0,003777	0,061455	36,8728	0,025089
PP2,2	0,142857	0,004440	0,066637	46,6458	0,025186
PP2,3	0,125000	0,005571	0,074642	59,7136	0,026390
PP2,4	0,111111	0,006049	0,077773	69,9955	0,025924
PP2,5	0,100000	0,006322	0,079512	79,5124	0,025144
PP2,6	0,090909	0,006477	0,080482	88,5307	0,024266
EP2	0,090909	0,006477	0,080482	88,5307	0,024266
PP3,1	0,038708	0,001054	0,032470	83,8853	0,006494
PP3,2	0,032258	0,000824	0,028705	88,9842	0,005155
PP3,3	0,031216	0,000519	0,022789	73,0064	0,004029
PP3,4	0,027778	0,000625	0,024992	89,9705	0,004165
EP3	0,027778	0,000533	0,023077	83,0755	0,003846
PP4,1	0,027778	0,000172	0,013117	47,2223	0,002186
PP4,2	0,021277	0,000067	0,008174	38,4175	0,001192
PP4,3	0,021277	0,000049	0,006987	32,8372	0,001019
EP4	0,021277	0,000049	0,006987	32,8372	0,001019
PP5,1	0,100000	0,003831	0,061892	61,8921	0,019572
PP5,2	0,100000	0,005612	0,074911	74,9109	0,023689
PP5,3	0,083333	0,006026	0,077626	93,1514	0,022409
PP5,4	0,071429	0,006008	0,077510	108,5141	0,020715
PP5,5	0,066667	0,005919	0,076933	115,3993	0,019864
PP5,6	0,062500	0,005802	0,076170	121,8714	0,019042
EP5	0,062500	0,005802	0,076170	121,8714	0,019042
PPA6,1	0,055556	0,001608	0,040094	72,1691	0,009450
PPA6,2	0,047619	0,001476	0,038418	80,6782	0,008384
EPA6	0,030543	0,000554	0,023542	77,0780	0,006292
PPA7,1	0,083333	0,000110	0,010497	12,5969	0,003030
PPA7,2	0,083333	0,001679	0,040973	49,1676	0,011828
PPA7,3	0,071429	0,000798	0,028245	39,5435	0,007549
EPA7	0,090000	0,000720	0,026833	29,8142	0,010954
PPA8,1	0,062500	0,000873	0,029552	47,2835	0,007388
PPA8,2	0,062500	0,000900	0,030000	48,0000	0,007500
EPA8	0,050000	0,000440	0,020976	41,9524	0,008563
PPA9,1	0,030303	0,000387	0,019670	64,9107	0,003424
PPA10,1	0,062500	0,001033	0,032146	51,4328	0,008036

Table 5: Cumulative Progress Data Planned and Executed by Projects (Example of 02 Projects).

N	Project N° 3					Project N° 4			
T	**PP3,1**	**PP3,2**	**PP3,3**	**PP3,4**	**EP3**	**PP4,1**	**PP4,2**	**PP4,3**	**EP4**
0	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
1	0,20%	0,20%	0,20%	0,21%	0,21%	1,00%	1,00%	1,00%	1,00%
2	0,41%	0,41%	0,41%	0,42%	0,42%	2,00%	2,00%	2,00%	2,00%
3	0,63%	0,63%	0,63%	0,63%	0,63%	3,00%	3,00%	3,00%	3,00%
4	0,83%	0,83%	0,83%	0,84%	0,84%	4,00%	4,00%	4,00%	4,00%
5	1,04%	1,04%	1,04%	1,04%	1,04%	5,50%	5,00%	5,00%	5,00%
6	1,81%	1,81%	1,81%	1,33%	1,33%	7,00%	6,00%	6,00%	6,00%
7	2,36%	2,36%	2,36%	1,80%	1,80%	9,00%	7,00%	7,00%	7,00%
8	3,71%	3,71%	3,71%	2,27%	2,27%	11,00%	8,50%	8,50%	8,50%
9	5,10%	5,10%	5,10%	3,35%	3,35%	14,00%	10,00%	10,00%	10,00%
10	6,38%	6,38%	6,38%	4,26%	4,26%	17,00%	12,00%	12,00%	12,00%
11	7,55%	7,55%	7,55%	5,16%	5,16%	23,50%	14,00%	14,00%	14,00%
12	10,37%	10,37%	10,37%	8,76%	8,76%	27,00%	16,00%	16,00%	16,00%
13	13,26%	13,26%	13,16%	11,75%	11,75%	30,00%	18,00%	18,00%	18,00%
14	16,69%	16,73%	16,55%	15,52%	15,52%	34,00%	20,00%	20,00%	20,00%
15	21,86%	19,95%	19,73%	18,07%	18,07%	38,00%	23,00%	23,00%	23,00%
16	29,08%	23,20%	22,75%	21,04%	21,04%	42,00%	26,00%	26,00%	26,00%
17	36,48%	27,17%	26,49%	24,80%	24,80%	46,00%	29,00%	29,00%	29,00%
18	43,89%	31,59%	30,58%	28,77%	28,77%	51,00%	32,00%	32,00%	32,00%
19	50,65%	36,64%	34,84%	33,77%	33,77%	55,00%	35,00%	35,00%	35,00%
20	59,16%	44,50%	40,69%	39,77%	39,77%	59,00%	38,00%	38,00%	38,00%
21	67,16%	52,29%	48,19%	43,75%	43,75%	63,00%	41,00%	41,00%	41,00%
22	74,41%	59,87%	52,96%	45,74%	45,74%	67,00%	44,00%	44,00%	44,00%
23	82,32%	67,28%	58,51%	46,84%	46,84%	71,00%	47,00%	47,00%	47,00%
24	88,68%	75,54%	64,32%	48,39%	48,39%	74,00%	50,00%	50,00%	50,00%
25	96,77%	83,38%	71,19%	50,76%	50,76%	77,00%	52,00%	52,00%	52,00%
26	93,77%	90,30%	78,42%	51,00%	51,00%	80,00%	54,00%	54,00%	54,00%
27	98,64%	95,86%	85,52%	52,06%	52,91%	83,00%	56,00%	56,00%	56,00%
28	99,13%	98,41%	88,46%	57,24%	56,71%	86,00%	60,00%	60,00%	60,00%
29	99,61%	99,81%	91,65%	60,95%	60,60%	88,00%	62,00%	62,00%	62,00%
30	99,80%	99,99%	94,68%	68,39%	64,39%	90,00%	63,00%	63,00%	63,00%
31	100,00%	100,00%	97,72%	76,75%	69,32%	92,00%	65,00%	65,00%	65,00%
32			99,89%	86,26%	74,66%	94,00%	67,00%	67,00%	67,00%
33			10,00%	91,80%	77,63%	96,00%	69,00%	69,00%	69,00%
34				96,60%	82,50%	98,00%	71,00%	71,00%	71,00%
35				99,80%	92,50%	99,00%	73,00%	73,20%	73,20%
36				100,00%	100,00%	100,00%	75,00%	75,40%	75,40%
37							77,00%	77,60%	77,60%
38							79,00%	79,90%	79,90%
39							81,00%	82,10%	82,10%
40							83,00%	84,30%	84,30%
41							85,00%	86,60%	86,60%
42							87,00%	88,80%	88,80%
43							89,00%	91,00%	91,00%
44							91,00%	93,30%	93,30%
45							93,00%	95,50%	95,50%