Review Article

Closing the Open System: Review of Nicolas Schöffer's La Tour Lumière Cybernétique (1973)

Nina Stener Jørgensen and Guillaume Laplante-Anfossi

Although never built, La Tour Lumière Cybernétique, the cybernetic light tower planned by Franco-Hungarian spatial artist Nicolas Schöffer (1912–1992) for Paris's La Défense business district in the 1960s and '70s, remains a compelling precedent of how a computational programme was thought to support a continuous and indeterminate design.

As tall as the Eiffel tower and illuminating the city with four thousand different light combinations calculated by its own computer, Schöffer imagined creating a spectacle on the Parisian horizon. [Fig. 1] By fixing blue, red, yellow, orange, violet and white light projectors and two thousand electronic flashes on a steel frame, together with 330 rotating mirrors and thirty-two propellers, the TLC tower was intended to simultaneously function as a work of art, a medium of communication and a cybernetic governmental tool.[1]

With no physical boundaries, as seen in the section, Schöffer reflected the tower's programmatic openness in the structure. [Fig. 2] The steel structure was intended to accommodate seven platforms reachable by elevators. The platforms would provide different typical 1960s leisure activities for visitors, among them a museum and a restaurant. However, the tower's main role would be to function as a cybernetic work of art, casting light and shadow over the city by extracting its data.

Although Nicolas Schöffer saw himself as a programmer, a role he deemed necessary for the artist to operate in a technologically advanced society, little attention has been paid to the algorithm he wrote for the TLC tower. In order to understand how Schöffer effectively imagined the tower to function, we turn towards the mathematical description of the programme that can be found in the appendices of *La Ville Cybernétique* (1969) and *La Tour Lumière Cybernétique* (1973).

In the text that accompanies the programme, Schöffer shows how the open-ended nature of the tower runs through the project on both a programmatic and conceptual level. Schöffer writes in 'La Tour Lumière Cybernétique' with regard to the aim of the project:

> The tower will certainly not be an end, but an example and a beginning. It will be a detonator opening the way to other achievements on other scales, which will be able to weave ever closer links between people and life with a view to their greatest success, that is to say their greatest happiness.[2]

However, in the mathematical description, the limits to the tower's openness and indeterminacy, bordering on programmatic abstraction, begin to reveal themselves. By definition, an open system is a system that has external interactions and is kept open through perturbations received from its surrounding environment. A perturbation is a disturbance that alters the behaviour of the system, and these are necessary in order to sustain the evolution of the system. Schöffer writes how the 'random coefficients', the perturbations, can be compared to the 'fantasy' or 'mood' of the tower, which he sees as necessary to ensuring that the tower's 'behaviour will

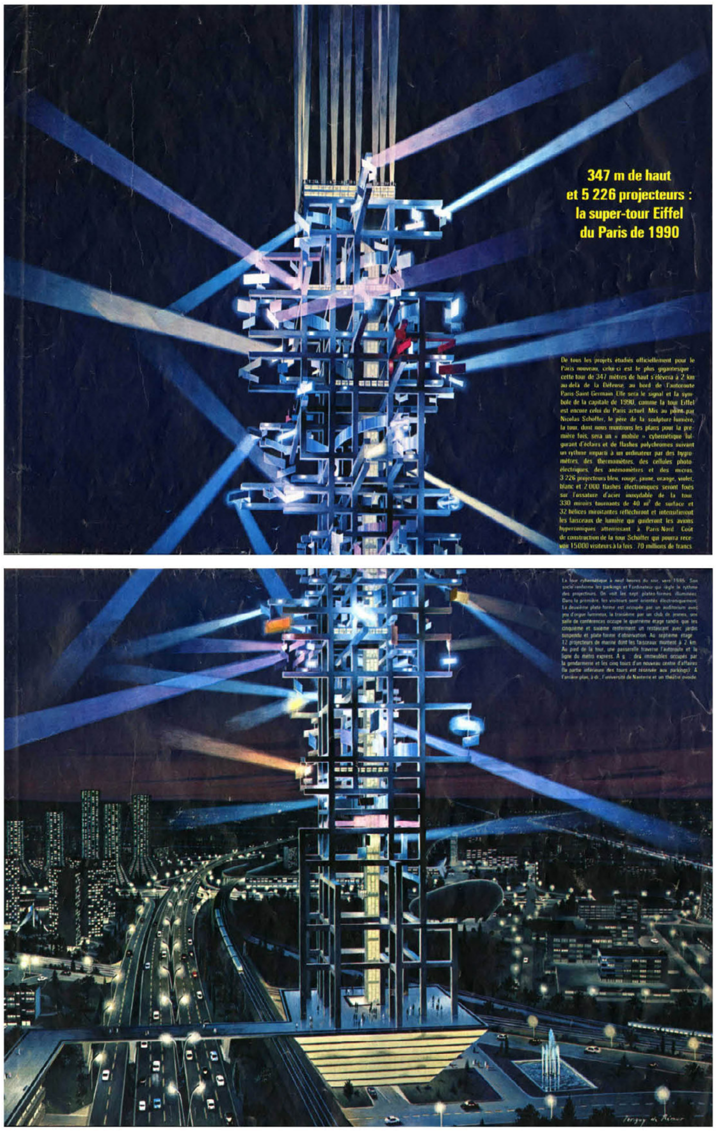


Fig. 1: La Tour Lumière Cybernétique in *Paris Match*, July 1967. Source: Paris-Match/Scoop.

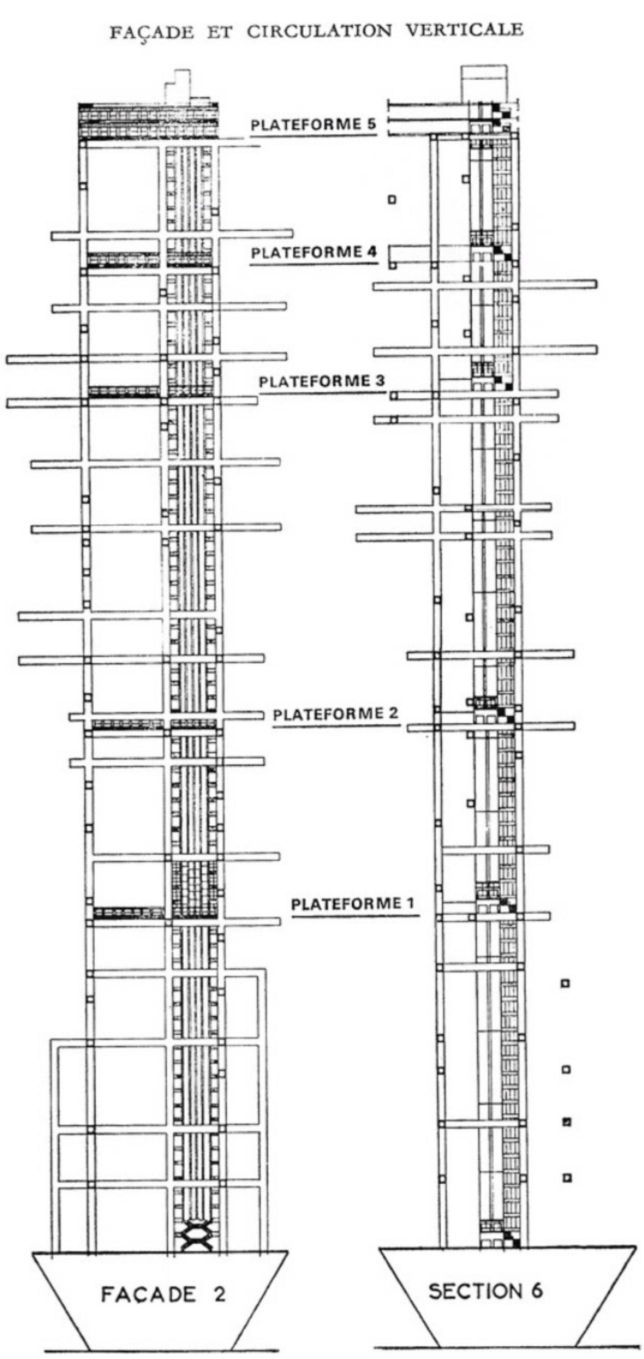


Fig. 2: A facade and a section of the tower of the tower as seen in Schöffer's *La Tour Lumière Cybernétique*, 1973. Source: ADAGP, Paris, 2022.

be unpredictable and non-repetitive'.[3] Yet, the way Schöffer deals with the system's need for disruption by treating all the incoming predictable data randomly suggests a potential for gradual monotony and saturation of the programme, precisely the effects which he sought to avoid.[4] In the simulation of the programme, Schöffer shows how the treatment of data is likely to create a monotonous blend of colours, light and sounds, an artistic choice, that we do not aim to criticise. Instead, we want to direct attention toward the choices Schöffer decided *not* to make, and to put forward the idea that in order to sustain an open system on both a conceptual and programmatic level, choices in the programme had to be made.

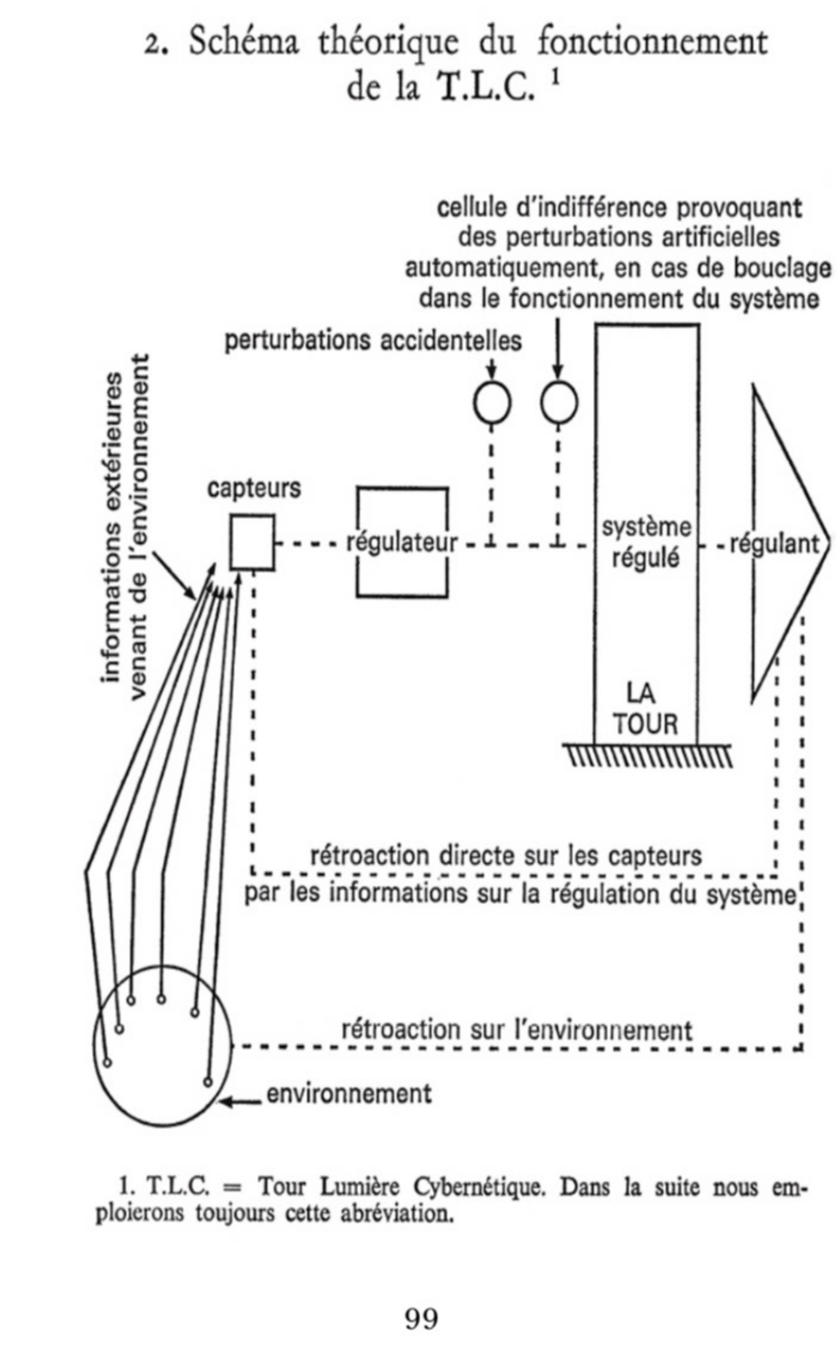
Between input and output

The arrival of cybernetics in 1948 with Norbert Wiener's *Cybernetics: Or Control and Communication in the Animal and the Machine* was especially important for the development of Schöffer's aesthetic theory.[5] When he presented the TLC tower as a 'cybernetic tower' he also presented it as a 'system' due to its reliance on the data it would retrieve from its surroundings.[6] To Schöffer the real gain of cybernetics was how it explained the relationship between information and feedback. He regarded it as 'the organised control of all information' and wrote about how cybernetics is the 'awareness of the vital process that keeps all phenomena in balance'.[7] Ideally, The TLC tower would keep Paris in check through an optimised feedback loop. In addition to the mathematical description and the written simulation he provided of the programme, Schöffer described the tower's interaction with the city through a feedback loop. [Fig. 3] In a diagrammatic way the loop described how the city's data was intended to interact with the tower, effectively illustrating what he saw as happening between input and output.

The input the tower would receive can be divided into two categories: immediate and remote. Input from its immediate environment would be grasped with the help of photocells, microphones, colour-sensitive cells, a thermometer, an anemometer (to measure wind speed), a hygrometer as well as an apparatus for the auscultation of the stresses in the tower's structure, that all would be attached to its steel frame. From the remote environment the tower would receive second-hand data such as the average of prices on the stock exchange, weather forecasts, information from the metro, the French press, traffic information from the police, information from hospital services, the post office, telegraphs and telephones, as well as the sound intensity from the back of the Chamber of Deputies.[8] Air navigation and information from the national radio and television would also be communicated to the tower via teletype and comprise all the input controlling and programming blue, red, yellow, orange, violet and white light projectors, electronic flashes, rotating mirrors and propellers that were imagined to be distributed all over the structure of the tower.

In the diagram, the tower is described as the loop's main system and its environment as its source of input. [Fig. 3] We see the sensors used to collect the data as well as the two controlling elements on either side of the tower, these refer to the orders of Schöffer's computer programme. In addition to the probability elements mentioned earlier, which are incorporated in the programme and do not appear in the diagram, we find two other small components that rely on probability and are meant as perturbations. Their job is to prevent repetition or stagnation in the output, and to go against too much excitation or relaxation by introducing a change to the received input. They are unfortunately not explained in full detail, and remain a conceptual element in the diagram.

In the following, we provide a description of what happens to the input when it enters the loop. It can be seen as a written translation of Schöffer's theoretical description achieved by a close reading of the written visualisation of the tower. It is worth mentioning that the written simulation does not incorporate all the elements of the theoretical description, and even



2. Schéma théorique du fonctionnement de la T.L.C. [1]

1. T.L.C. = Tour Lumière Cybernétique. Dans la suite nous emploierons toujours cette abréviation.

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Fig. 3: Nicolas Schöffer described the TLC tower as a feedback loop in *La Tour Lumière Cybernétique*, 1973. Source: ADAGP, Paris, 2022.

some of the elements that are incorporated are modified. In a sense, it seems to be Schöffer's intention to keep the rules rather simple and the method flexible in order to adapt the programme to any situation. However, reading the programme provides its own set of challenges: many details are missing and mathematical notations are used ad hoc, resulting in apparent contradictions and ambiguities. We have tried to adhere to Schöffer's choice of using mathematical language to express his idea, but we attempt to make it accessible by relating it to the imagined functioning of tower. We retain the formulas and formal language, should anyone wish to programme it further.

The computer's programme

In the programme, the tower's inputs at any given time are denoted x_1, x_2, x_3 and so on, up to x_n, the letter n signifying the number of inputs. The input x_1 could represent the number of trains in Gare du Nord, while the input x_2 could represent the number of visitors at the Louvre and x_3 the intensity of sound recorded around the tower. Each of these inputs is represented by a number between 0 and 1, mirroring the degree of activity of the associated data. To compute x_1 in the programme, the computer divides the number of trains at Gare du Nord at a given time by the maximum number of trains. This number will be used to activate output. In order for the computer to figure out how to activate the large amount of output available (the rotating mirrors, the coloured lights, the tower's propellers), Schöffer divided them into groups; in the programme, the letter q stands for the number of groups. At a given time, the programme receives the inputs x_1, x_2, x_3, …, x_n and according to these numbers, some groups of outputs are activated while others are not. For the purpose of determining which groups are activated, Schöffer designed a set of functions X_1, X_2, X_3, …, X_q; each of which is assigned to a group of outputs (not to be confused with the lowercase x_i that denotes input).

The functions X_1, X_2, X_3, …, X_q, which can be seen as the disposition of the outputs, do not change, but are assigned to different groups of output over time. The functions are computed according to the inputs and return either the number 1 or the number 0, indicating whether the corresponding group of outputs should be activated or not. Returning either 1 or 0 is determined by the function's sensitivity to the inputs. For example, the function X_1 could be very sensitive to the trains at Gare du Nord, moderately sensitive to the number of visitors at the Louvre, while not taking into account the decibel level around the tower. However, the design of the function X_i (the letter i stands for any number between 1 and q), also involves a range of sensitivity, meaning that the output controlled by this function can be either easy or difficult to activate, depending on parameters that are set a priori by a programmer.[9] Mathematically, the programme computes the value of a function X_i according to the following formula:

$$(*)\sum_{j=1}^{n} A_{ij}x_j - B_i = A_{i1}x_1 + A_{i2}x_2 + \cdots + A_{in}x_n - B_i$$

If this sum is positive, meaning greater than zero, then X_i is set to 1 and the group of output is activated. If it is below 0, meaning negative, X_i is set to 0 and the group remains disabled. In the formula, the x_j are the input at the time of computation, the coefficients A_{ij} are numbers between 0 and 1, and the coefficient B_i is a positive number (it can be greater than 1). The coefficient A_{ij} can be interpreted as 'the sensitivity of the function X_i to the input x_j'.[10] For instance, if $A_{ij} = 0$, the input x_j does not contribute to the sum (*) since it is multiplied by $A_{ij} = 0$, and thus it is not taken into account for the sake of activating the outputs (associated with X_i). In a similar way, if $A_{ij} = ½$, the input x_j is partially (one could say 'half') taken into account, and if $A_{ij} = 1$, it is completely taken into account. The result of the sum (*) is the cumulative contribution of the different inputs, weighted by the different 'sensitivities' A_{ij}.

The coefficient B_i represents 'the global sensitivity of the function X_i to the input'.[11] This means that if the coefficient B_i is large, then the function X_i needs the inputs x_j to be large in order for the sum (*) to be bigger than B_i, so the function X_i is in this case not very sensitive to the activity in the city. On the contrary, if B_i is small, only a few of the inputs x_j needs to increase in order for the sum (*) to be bigger than B_i, so the function X_i is in this case very sensitive to the activity in the city.

Schöffer writes that the coefficients A_{ij} and B_i should be chosen either randomly or according to an 'artistic criterion', which unfortunately he does not specify.[12] Here, 'choosing randomly' means 'choosing according to a probability distribution', which is a simple task for the computer, but Schöffer does not say which probability distribution to choose, and instead uses in the simulation a uniform distribution, one where all numbers between 0 and 1 are equally likely to be chosen.

As we explained before, the coefficients A_{ij} and B_i defining the function X_i are chosen only once. Periodically (though no precise time scale is provided here), the functions X_1, ..., X_q are reassigned to different groups of outputs. This reassignment is done randomly, through a process where essentially all groups of outputs are equally likely to be chosen. As Schöffer is vague about this part of the computation, it is difficult to describe it any further, and unfortunately, the simulation does not integrate this periodic change of assignment of the X_i functions. We can deduct from Schöffer's description that it might be a matter of minutes between the groups' re-assignments, but it is important to stress that we cannot be sure. However, one could imagine the following situation: for five minutes a group of mirrors is sensitive to the number of trains in Gare du Nord, and then for the next five minutes it is moderately sensitive to the visitors at the Louvre, while the red lights are then very sensitive to the number of trains in Gare du Nord, and so on.

It seems noteworthy that Schöffer also required a certain number of the X_i functions to permanently take the value 0; he did not however specify the exact proportion of the X_i functions that should do so. This suggests that he wants, at any given time, to leave a certain number of the outputs disabled. We can imagine that, according to the periodic reassignment of the X_i functions, the inactive outputs of the tower would change randomly, that is, move from one part of the tower to another, with all parts of the tower being equally likely to be chosen in each reassignment. For example, the mirrors could be inactive for five minutes, and then the red lights would be inactive for five minutes, then the blue lights, and so on. We could imagine a period of five minutes where the X_i functions have been assigned to the groups of outputs and stay the same. Starting at the beginning of the five-minute period, the values of the X_i functions are computed according to the inputs entering the programme at that time, as described in the formula (*) above. For a function X_i taking the value 1, a random time of activation Y_i is then computed, and a 'mode of operation' is chosen at random. Schöffer describes how a 'mode of operation', which is a sub-programme, made in advance and stored on the tower's computer, can be used to activate any group of outputs. For example, one mode of operation can activate the outputs of the group from left to right, or right to left, meaning that the lights, mirrors or propellers are activated from left to right on the tower's frame. Interestingly, Schöffer planned fifty such programmes to be written in advance, and did not leave this part of the programme open. The time Y_i is chosen within an unspecified time range, and according to a probability law (which is also not specified, and is to be made 'according to artistic criterions').[13] The group of outputs associated with X_i is then activated during the time Y_i. After that, the function X_i is computed again with new inputs. For a function X_i taking the value 0, a random time of activation Y_i is computed and the corresponding group of outputs is left disabled. After that time has elapsed, the function X_i is computed again with a new set of inputs. To sum up, each function is sensitive to different input; some are sensitive to trains, some to the stock market. Every five minutes the functions are assigned to different outputs, meaning that sometimes the number of trains light up red lights, while sometimes they turn on the propellers.

The Y_i functions in the programme are those that determine how many times during the activation period the tower receives and reacts to input.[14] This could happen as many times as computation time allows for during a period or only once.

We could imagine the following behaviour, supposing that the function X_i governing the red-light group is sensitive to the trains in Gare du Nord for five minutes. If there are a lot of trains in Gare du Nord, during the first minute, the red lights are activated. The time of activation and the mode of operation, chosen at random, are one minute and left-to-right behaviour, which means that the red lights behave in this way for one minute. If, at the start of the second minute, in the five-minute period, there are far fewer trains in Gare du Nord, the lights are not activated. The random time of activation is then two minutes, so the lights stay off for two minutes and so on for the remaining minutes. At the end of the five minute-period, the function X_i is assigned to another group of outputs (for instance, the mirrors), and the process is iterated.

We have remarked that except at the beginning of the programme, the functions X_i will in general not be calculated at the same time, which means that the effect of an important change in the inputs will not necessarily impact the entire tower at the same time, and that the delay during which it will do so relies heavily on the choice of range and probability distribution for the times of activation Y_i.

Closing the open system?

Upon reviewing the programme, several programmatic as well as conceptual problems become apparent, the main one being the programme's reliance on probability for perturbations to the system. Reading the programme suggests that the stagnation Schöffer imagined he could avoid by treating the input according to probability laws could in fact reinforce monotony. To see this, we have to turn to the laws of probability. A probability distribution is a representation of the probability of each event within a fixed number of possibilities. A probability is conventionally represented by a number between 0 (impossible event) and 1 (certain event), the sum of the probabilities for all possible events being 1.[15] In practice, probabilities are interpreted statistically: when we say, for example, that the probability of 'obtaining an even number when throwing a die' is 1/2, we mean that if we throw the die a large number of times (1000, for example) and repeat this process several times, we will obtain a proportion of 50 per cent of even numbers (or very close to it; the more attempts we make, the closer we get to this proportion). Thus, a series of events ruled by a probability distribution are almost impossible to predict 'locally' (the number that appears after throwing the die once) but easy to predict 'globally' (numbers that appear in 1000 throws of the die). This means that the tower would appear unpredictable and non-repetitive within a short time frame (such as five minutes), but within a longer time frame (an hour, a day, a week) it would be extremely similar to itself. The same phenomenon would occur spatially. Someone looking very closely at the tower (a person working in La Défense, or one of the tower's visitors) would not see any pattern (for example, colours changing constantly around him), but someone looking at it from far away would see some pattern (for example always around 60 per cent of the blue lights would be on). This phenomenon would even be independent of the precise probability distributions chosen. Of course, the tower would look different (both locally and globally) with a different choice of distributions, but it would always be globally similar to itself with respect to both space and time. In order to avoid this, Schöffer would have to make an even more sophisticated programme, for example by changing the probability laws over time, or by shaping the laws according to the inputs. Unfortunately, the perturbations, introduced by Schöffer to avoid repetition and predictability, would have the opposite effect. Moreover, looking at the very large number of inputs, treated only as a *volume* of information (the nature of inputs is not taken into account), combined with its treatment via many probability distributions, one could even doubt that the tower would reflect the city in any way: it could simply result in a big 'blur'. Seen as an open system, the tower could finally behave as if it were not interacting with its environment. To avoid this, the artistic criteria mentioned by Schöffer in his description of the programme would have to be specified. By leaving these choices 'open' it seems Schöffer is instead slowly letting his system close in on itself.

Notes

1. Nicolas Schöffer, *La Tour Lumière Cybernétique* (Paris: Denoël/Gonthier, 1973), 74.
2. Nicolas Schöffer, *La Ville Cybernétique* (Paris: Tchou, 1969), 185; Translation by the authors.
3. Section 6, 'Introduction to the simulation' (Simulation du fonctionnement et visualisation de certains élément de la T.L.C.), Schöffer, *La Tour Lumière Cybernétique*, 112.
4. 'It will be necessary to install a disruption system that will intervene each time there is a tendency to repetition, saturation or stagnation of programmes (an abacus for example).' Schöffer, *La Tour Lumière Cybernétique*, 100; Translation by the authors.
5. Schöffer, *La Tour Lumière Cybernétique*, 6–7.
6. Ibid., 5.
7. Schöffer, *Le Nouvel Esprit Artistique* (Paris: Denoël/Gonthier, 2018 [1970]), 12; Translation by the authors.
8. Schöffer's humorous way of describing the often heated debates of the Assemblée Nationale, the French parliament.
9. Schöffer does not specify what these parameters would look like, but maintains them as artistic criteria to be determined.
10. Schöffer, *La Tour Lumière Cybernétique*, 120.
11. Ibid.
12. Ibid.
13. Ibid., 111.
14. In contrast with the $X_{\_i}$ functions, Schöffer does not provide a formula for the $Y_{\_i}$ functions.
15. For example, the probability distribution associated to the roll of a die is called 'the uniform distribution': each of six possible outcome 'rolling the die and getting the value n' , for n=1, 2, 3, 4, 5 or 6, has the same probability, 1/6. The sum of these six probabilities is 1, the certain event.

Biography

Nina Stener Jørgensen is a PhD student at the Estonian Academy of Arts, Faculty of Architecture. Studying architectural models of participation from the 1960s in light of today's so-called smart city, her PhD research focuses on producing a genealogy of what could be referred to as a post-participatory condition in architecture.

Guillaume Laplante-Anfossi is a PhD student in mathematics at the Université Sorbonne Paris Nord. His research on operads and polytopes focuses on the study of higher algebraic structures arising in algebraic topology.