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Fuzzy Cognitive Maps Theory: Implications for Interdisciplinary Reading: National Implications

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ABSTRACT

Fuzzy Cognitive Maps (FCMs) are initially shown to have evolved from Cognitive Maps (CMs). The components and functions of FCMs are described and their superiority over CMs is explained. A hypothetical fuzzy cognitive map, employing a nine-step procedure and data tables, is then used to demonstrate the impact of drug addiction in America. Conclusions are subsequently derived from these data tables, and implications for interdisciplinary reading are provided.

Fuzzy Cognitive Maps Theory: Implications for Interdisciplinary Reading

Robert Axelrod (1976) inaugurated the use of cognitive maps (CMs) for formally modeling decision making processes associated with political and social systems. CMs are directed graphs capable of modeling interrelationships or causalities existing amongst concepts (nodes). Concept variables and causal relations constitute the two fundamental elements that CMs employ for graphically describing systems. Concept variables are represented by nodes, such as C_1, C_2, C_3, and C_4 in Figure 1, a basic CM having four concept variables describing the impact of drug addiction. Causal variables always depict concept variables at the origin of arrows; effect variables, on the other hand, represent concept variables at the terminal points of arrows. For example, in looking at $C_1 \rightarrow C_2$ in Figure 1, C_1 is said to impact C_2 because C_1 is the causal variable, whereas C_2 is the effect variable.

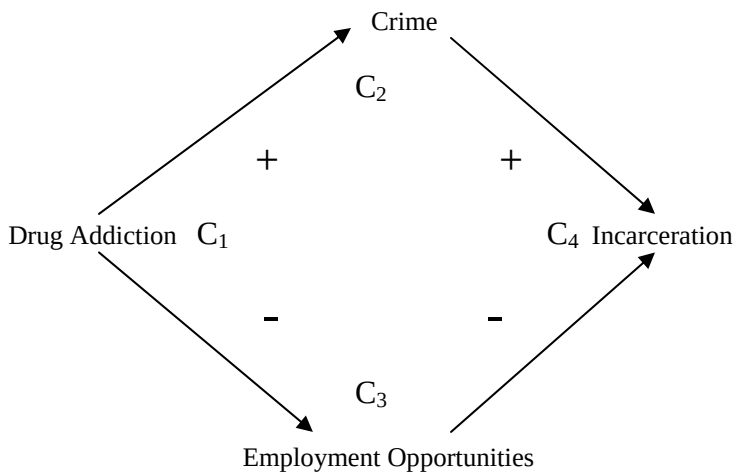

Figure 1 - A traditional cognitive map on the impact of drug addiction

According to Alexlrod (1976), causal variable C_1's total effect on effect variable C_4 is the aggregate sum of all the paths' indirect effects from each causal variable associated with each effect variable. A positive total effect implies that each indirect effect is also positive; a negative total effect implies that each indirect effect is also negative; an indeterminate effect, on the other hand, implies that some indirect effects manifest positive effects while others manifest negative effects (Kosco, 1986). Unfortunately, when cognitive maps contain many concepts and paths, indeterminacy dominates. For example, in Figure 1 above, C_1's total effect on C_4 is indeterminate. This intrinsic drawback persists because cognitive maps cannot accommodate knowledge-based building since causality itself generally tends to be fuzzy because it admits of vague degrees [e.g., a little, some, often, much, usually, very much] (Fons, S., Achari, G., & Ross, T.J., 2003).

Fortunately, Kosco (1986, 1992) introduced fuzzy cognitive maps (FCM) that augment a CM's power by accommodating the aforementioned knowledge-base building feature, because FCMs are capable of modeling cyclically dynamic systems, which in turn permits feedback within a cycle. FCMs, which are typically dependent upon experts' input, may be thought of as fuzzy-graph structures that represent the fuzzy nature of causal reasoning by permitting vague degrees of causality between vague causal concepts. Their graph structure, moreover, thrives on feedback and can connect various FCMs to propagate knowledge bases.

Figure 2, a FCM describing the impact of drug addiction, associates fuzzy values with each of the cognitive map's concepts and uses fuzzy degrees as the metric for designating the interrelationships between concepts**.** In essence, a FCM is a signed directed graph that entails feedback and employs concepts (nodes) and weighted edges (arcs) between concepts. Nodes of the graph designate each concept that represents a system variable (e.g., actions, events, goals, policies, processes) whose values vacillate.

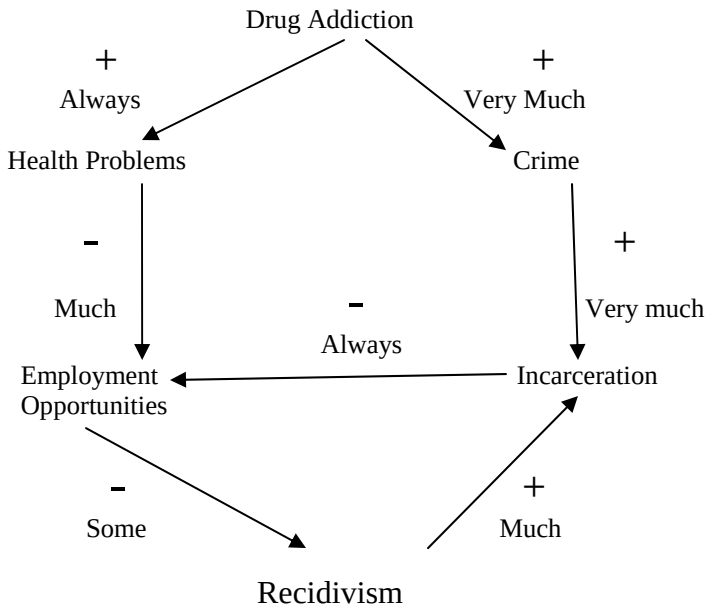

Figure 2 - A fuzzy cognitive map on the impact of drug addiction over time

Signed and weighted edges, on the other hand, express the causal relationships existing between any two concepts. In addition, a directed edge may connect any concept not only to any other concept but also to itself, signifying that a concept's current value determines its future value. In fact, all of a FCM's values are fuzzy. Accordingly, each concept's value is influenced by its previous value and the connected concepts' values accompanied with their appropriate weights. Hence, it is a FCM's memory capabilities that enable it to demonstrate how a change in one concept's value affects the entire FCM by keeping track of the concept's old and new values following each of the FCM's new cycling, runtime, or simulation. For example, in using a unipolar threshold function, weighted values for concepts or nodes traditionally range from 0 to 1, with 0 indicating maximum negative representation, 0.5 representing ambivalence, and +1 indicating maximum positive representation. Connecting edges, which indicate the degree of causality between any two concepts, traditionally employ a bipolar threshold function ranging from -1 to +1, with -1 reflecting a strong negative impact, through 0 reflecting no impact, to +1 reflecting a strong positive impact (Brubaker, 1996).

In Figure 2, word weights like "some" and "always" denote the causal relationships between concepts, and the symbols "+" and "-" denote the type of relationship between concepts. A fuzzy rule, causal link, or connection is defined by each arrow in the same figure: A plus (+) represents causal increase, and a negative (-) represents casual decrease. According to the plus rule, for example, if drug addiction increases, then health problems increase to some degree, too; if drug addiction decreases, however, health problems decrease to some degree, too. The minus rule, in contrast, implies that if health problems increase, then employment opportunities decrease to some degree. Hence, the plus rule and the minus rule exhibit a directly proportional and inversely proportional relationship, respectively.

A typical runtime operation, or simulation, of a FCM entails the following general procedures: First, drawing an FCM via an expert's (or experts') experience and expertise regarding a system's operation is arguably the most pivotal step. The expert (or experts) identifies the appropriate concepts most crucial in modeling the system, determines each concept's negative or positive effect on other concepts, and assigns fuzzy values for all events or interconnections. Second, with the successful construction of the FCM, it is now possible to model and simulate the system's behavior. At this juncture, the FCM is ready to be initialized. This means that the expert(s) assigns each concept an activation level having an initial value ranging in the interval [0,1]. Third, the concepts are then free to interact, resulting in the concepts' values changing during each step of the cycling process or runtime operation. Fourth, contingent upon the quantity of concepts and the quantity and complexity of events or interconnections, the system normally necessitates several steps or cycles before it reaches equilibrium, i.e., when a system ceases to change. It is, however, quite possible that the system may not even reach equilibrium. When this happens, it does so because a FCM's feedback paths render the FCM oscillatory, which may occur either predictably or chaotically, or the paths render the FCM unstable.

As previously stated, FCMs are significantly more flexible, valuable, and efficient than are CMs for analyzing a system's major components and the causal connections that exist amongst them, due primarily to their knowledge-base building capacities and feedback. FCMs, in fact, are now used extensively for planning and decision-making in numerous fields, especially in the physical and social sciences (Stylios, C.D., Georgopoulos, V.C., & Groumpos, P.P., n.d.). In the next section, a practical problem will be employed to demonstrate how a FCM functions.

Implementation of a FCM on Drug Addiction

In this section, the problem of drug addiction, with its national and international implications, will be modeled to obtain a feel regarding how a FCM typically works. Drug addiction, fortunately, possesses three intrinsic characteristics that make it ideal for analysis via fuzzy cognitive maps: First, it is a problem having many factors that contribute to its complexity; second, modeling it mathematically is impossible because it cannot simply be reduced to equations; and third, the problem is subject to various interpretations because it can be perceived from different perspectives. In order to demonstrate drug addiction's ideal choice for analysis via FCMs, this manuscript will focus next on the preparation of a hypothetical fuzzy cognitive map, whose topic is based in part on Kosko's (1993) work, for problems associated with drug addiction. Results of hypothetical simulations for the fuzzy cognitive map are provided, and hypothetical conclusions are drawn from them.

Step 1: Identification of Factors or Concepts

Based on Aspuru's (n.d.) work, nine steps are employed in designing a cognitive map: (1) identification of factors, (2) specification of relationships, (3) levels of all factors, (4) intensities of causal effects, (5) changeable factors versus dependent factors, (6) simulating the fuzzy cognitive map, (7) modifying the fuzzy cognitive map, (8) simulating the modified fuzzy cognitive map, and (9) conclusions.

The first step when preparing a fuzzy cognitive map entails the identification of and rationale for those requisite factors (concepts) that constitute part of it. The following eight factors (concepts) have been selected, based on the author's interpretation of the current status of the impact of drug availability and drug usage in America.

Drug Usage. Drug usage is a problem that plagues many citizens in our country; unfortunately, it is a global problem, too. The goal set for this hypothetical fuzzy cognitive map is to determine how drug usage impacts America. Hence, it, along with drug availability, is the most critical factor in this fuzzy cognitive map. Drug usage will be shown to affect other factors in the FCM.

Drug Availability. As long as there are drugs, drug usage will inevitably occur due to human nature; nonetheless, reducing the availability of drugs in its various forms, both domestically and internationally, should help to diminish its usage. This factor, along with drug usage, is the most critical factor in the cognitive map; it will also be shown to impact other factors in the FCM.

American Police Interdiction. The degree to which America's various levels of law enforcement agencies are adequately funded determines to a great extent whether we will succeed in reducing drug usage in our country. This dimension of enforcement will be shown to be a pivotal factor in successfully reducing drug usage, but not sufficient, alone. This interdiction also affects other factors in the FCM.

International Police Interdiction. Given that drug usage is a global problem, it should come as no surprise that law enforcement at the international level is essential in combating the flow of drugs to America as well as to other parts of the world. This dimension of law enforcement, while central for solving drug addiction within our borders will also be shown to be insufficient, alone. This level of interdiction also affects other factors associated with this FCM.

Treatment Centers. As long as drugs are available and used by our citizens, treatment centers will be needed to help rehabilitate their lives in order to become productive citizens. Although this is but one approach for dealing with the drug issue in this country, it is an essential one.

American Image. How America is viewed by other nations is important for our international relations with other nations. Hence, our ability to properly and effectively deal with drug availability and drug usage problems reflects the kind of people we are. This factor also impacts other factors in the FCM.

Economic Productivity. Our nation's ability to generate wealth and revenues is highly dependent upon employees and entrepreneurs who are productive, dependable, and reliable. Drug availability and drug usage, on the other hand, nullify these essential attributes of economic productivity.

Tourism. Our nation's ability to attract tourists is an indication of our standing in the international community. Thus, it is imperative that we deal appropriately with drug availability and drug usage issues. Tourism also affects other components of the FCM.

Step 2: Specification of Relationships

The second step in preparing fuzzy cognitive maps establishes the causal relationships (positive, negative, or neutral) amongst the various factors (concepts). This is a critical step because an articulate analysis is required to determine how and why the values of factors or concepts change over time.

Causes of Drug Usage. The first and major cause of drug usage in America is the availability of numerous addictive drugs, whether produced domestically or internationally. Moreover, the causal relationship is positive (increased availability, increased addiction; decreased availability, decreased addiction).

Causes of Drug Availability. Drug usage is the major reason for drug availability because there is a tremendous global demand for the illicit use of drugs. Drug usage, hence, is a positive cause of drug availability.

Causes of American Police Interdiction. Drug usage is the major cause for American police interdiction because of the problems posed by drug users in this country. Monies must be allocated for police forces at all levels of government in order to resolve this major issue confronting us. Drug usage is a positive cause of American police interdiction. Drug availability is naturally another major cause of American police interdiction because so many drug users do drugs because they are available. Drug availability is a positive cause of American police interdiction.

Causes of International Police Interdiction. Drug usage is a major cause of international police interdiction because the problem exists on a global scale. Therefore, international cooperation is imperative if the problem is to be resolved satisfactorily. Drug usage undoubtedly is a positive cause of international police interdiction. Drug availability is another major cause of international police interdiction because without a source, there is no drug problem. Unfortunately, drugs are harvested and processed in laboratories around the world. Consequently, drug availability is a positive cause of international police interdiction.

Causes of Treatment Centers. Treatment centers are needed to rehabilitate citizens who have fallen victim to drug usage. As a result, they can become productive citizens again in society. Drug usage is a positive cause of treatment centers. Drug availability is another cause of treatment centers because without drugs, such centers would not be needed. Drug availability is a positive cause of treatment centers.

Causes of American Image. Clearly, there are many factors that contribute to a nation's image on the international stage. Drug usage categorically impacts the image of the U.S.A. around the world, based especially upon how we respond to the problem. Drug usage is a negative cause of our American image. Drug availability is another

factor that affects our image on the international scene because it, too, reflects our ability to respond to this problem. This factor negatively affects our American image. Treatment centers also impact America's image because it reflects a humane attitude toward human failures and a desire to enable them to become more productive citizens once again. This factor negatively affects our American image. Tourism also impacts America's image because, amongst other things, increased tourism reflects a desire amongst foreigners to want to visit our country. In general, an increase in tourism tends to reflect a favorable image of our country. Hence, this factor positively affects the American image.

Causes of Economic Productivity. A nation's economic productivity, to be sure, is caused by numerous factors. For purposes of this article, only pertinent factors associated with this FCM will be addressed. Drug usage impacts our economic productivity; however, it does so negatively because increasing drug usage tends to decrease employees' productivity. Drug availability also negatively impacts economic productivity because increasing access to drugs tends to increase drug usage, which in turn decreases one's productivity. Tourism is another cause of economic productivity because tourists spend much money when they visit America, which in turn increases our national wealth. This factor is a positive cause of tourism.

Causes of Tourism. Our American image is an important cause of tourism in our country because our international standing will either attract or repel potential visitors to our shore. This factor is a positive cause of tourism. Drug usage is another important causal factor of tourism because greater usage of drugs may translate into fewer foreigners willing to visit our shores. This is a negative casual factor. Drug availability is also a negative causal factor of tourism because easy access to drugs may turn off potential foreign visitors.

Factors Without Causes. In viewing the various factors associated with this fuzzy cognitive map, none is seen as existing without any causes because each factor is caused by one or more other factors in the fuzzy cognitive map. Naturally, this interpretation could be challenged.

Illustration of the Fuzzy Cognitive Map. Figure 3 below represents all eight factors or concepts of this hypothetical system's fuzzy cognitive map.

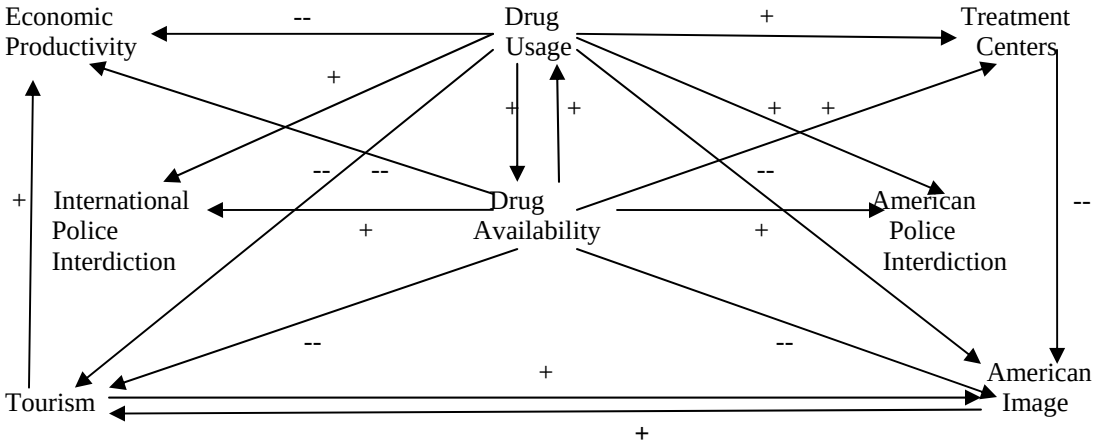

Figure3: A fuzzy cognitive map on the impact of drug addiction in America

In the next section below, the third step, the levels (ranging from 0-100) of each factor (concept) within the system will be discussed.

Step 3: Levels of all Factors

It can be assumed that the problem of both drug usage and the availability of drugs in the U.S.A. is essentially a constant one, rather than one that simply evolves. Drug usage, overall, changes very little: drug users seek drugs; pushers provide the supplies, and law enforcement agencies attempt to stem the tide. We have a major problem within our borders and little light at the end of the tunnel.

Based on the above assumption, levels of 50 (out of 100) can be assigned to represent the levels of each of the eight factors of the FCM, resulting in a steady state such that none of the eight factor levels induces a change in the level of any of the remaining factors. Verification that no evolution has occurred can be verified through simulations on the FCM and checking after several iterations.

Allocating levels of 50 to each of the eight factors of the FCM should not be construed as meaning, in absolute units, that equality exists amongst all factor levels. This apparent confusion can be explained by stating that each factor actually has its own unique level, measured in units perhaps non-applicable to the remaining factors. In other words, having identical values representing various absolute quantities in various factors is irrelevant because the simulation process does not employ these values to compare one factor's level with a different factor's level. Rather, the values are employed for comparing one factor's level prior to the simulation with the same factor's level after the simulation run. The simulation is conducted after generating a perturbation within the system in order to knock it out of its steady state. Any variation in one or more of the factors' levels constitutes a perturbation within a system.

Step 4: Intensities of Causal Effects

According to the fourth step, all causes affecting a factor vary in intensity or degree. For example, although drug usage and tourism are causes of economic productivity, drug usage affects economic productivity more so than does tourism. Hence, various causes' intensities of effect are reflections of their relative significance, extending from 0 (no intensity) to 100 (uppermost intensity). Based on Aspuru's (n.d.) work, three ranges of intensities of effect are employed: high intensity (with an assigned value of 75 out of 100), moderate intensity (with an assigned value of 50 out of 100), and low intensity (with an assigned value of 25 out of 100). Each group's relationships are listed below.

High intensity relationships:
Drug availability causes drug usage
Drug usage causes drug availability

Moderate intensity relationships:
Drug usage causes American drug interdiction
Drug usage causes international police interdiction
Drug usage causes tourism
Drug usage causes American image
Drug usage causes economic productivity
Drug availability causes American police interdiction
Drug availability causes international police interdiction
Drug availability causes tourism
Drug availability causes American image
Drug availability causes economic productivity

Low intensity relationships:
Drug usage causes treatment centers
Drug availability causes treatment centers
Tourism causes economic productivity
Tourism causes American image
American image causes tourism
Treatment centers cause American image

The above matching of intensities of effects with relationships is assuredly only one way of matching various numeric values corresponding with the three categories of intensity: low, moderate, and high. Furthermore, the relationships could have been grouped differently, or a different number of groups could have been selected. In the next section below, the fifth step, a distinction is drawn between changeable and dependent factors.

Step 5: Changeable Factors Versus Dependent Factors

The fuzzy cognitive map's changeable factors associated with the impact of drug usage in America are drug usage, drug availability, American police interdiction, and international police interdiction. The dependent factors, in contrast, are American image, tourism, economic impact, and treatment centers.

The "agents" associated with the changeable factors have a choice of modifying or resuming their behavior and objectives, thereby affecting the evolution of the entire system. More specifically, the "agents" of these changeable factors are able to directly control the systems' factors and to modify these factor's levels at will. However, the "agents" are unable to directly control other factors' levels, i.e., dependent factors. For

example, in terms of independent factors, the drug user could have initially decided not to do drugs by not getting involved with drugs; all parties responsible for making drugs globally available could cease to do so; different governmental levels in the U.S. could simply decide to use monies to have police focus on global terrorism rather than on drug usage; and foreign countries could decide, too, to spend monies to have their police focus on global terrorism rather than on drug usage, or they could continue to support global drug usage without providing help for America. On the other hand, relative to dependent factors, America's image depends on many factors other than drug usage at any given moment; tourism, also, is dependent on factors other than drug usage; many factors, other than drug usage, have an economic impact on America's economy; and allocating monies for treatment centers are dependent upon many factors at any given time and must compete against other social needs vying for financial support.

Hence, drug usage, drug availability, American police interdiction, and international police interdiction are the four factors that can be directly changed and will be employed in an attempt to diminish the impact of drug usage in the United States for purposes of this FCM.

Step 6: Simulating the Fuzzy Cognitive Map

In this section, the sixth step, running simulations on this hypothetical fuzzy cognitive map implies introducing variations in all four changeable factors, enabling us to perceive each changeable factor's impact on the whole system. Each factor's level fluctuates, rather than remains immutable, when it is modified in the fuzzy cognitive map and subsequently undergoes simulation runs. Realistically, each factor's level during a simulation run evolves simultaneously with all other factors, i.e., the initial variation in the factor's level functions as a perturbation that causes the whole system to lose its equilibrium, causing the system to evolve until it reaches equilibrium again. What is needed, consequently, is the acquisition of a perturbation that drives the system to a new equilibrium state that is better than the old equilibrium state. In this hypothetical fuzzy cognitive map, "improved" implies that it produces a lower level of drug availability and drug usage-related problems in America.

6.1 Effect of Drug Usage

Table 6.1 below shows that drug usage is the first factor to be changed and that simulations have been run for selected values. The table reveals the simulations' final state for various initial values associated with drug usage.

Factor	Drug Usage					
	0	20	40	60	80	100
American Image	90	85	80	50	40	10
Tourism	90	90	75	30	30	30
Drug Usage	45	47	50	54	57	59
Drug Availability	23	29	35	41	46	56
Treatment Centers	12	17	37	57	78	91
Economic Productivity	90	75	40	20	15	10

Table 6.1

As is evident from Table 6.1, drug usage's initial and final levels differ. An initial decrease in drug usage improves America's image, tourism, and economic activity while decreasing drug availability, the need for treatment centers, and drug usage, but not so much. When initial drug usage is high, however, the final state reverses itself: a decrease in America's image, tourism, and economic activity, while increasing drug availability, drug usage, and the need for treatment centers.

6.2 Effect of Drug Availability

The second set of simulations via Table 6.2 examines the effect of drug availability; it, too, as before, employs a sample of initial levels for drug availability in running the simulation.

Factor	Drug Availability					
	0	20	40	60	80	100
American Image	90	85	82	53	41	13
Tourism	90	88	75	32	32	32
Drug Usage	43	46	51	54	55	60
Drug Availability	23	29	36	40	45	55
Treatment Centers	10	15	30	55	75	90
Economic Productivity	89	73	40	21	14	9

Table 6.2

Close inspection of Table 6.2 reveals that the effects of a decrease or increase in the level of drug availability and the effects of a decrease or increase in the level of drug usage mirror each other at corresponding levels. These symmetrical results should not surprise us because of the strong positive correlation between both factors.

6.3 Effects of Drug Usage and Drug Availability

This third set of simulations in Table 6.3 explores variations of both factors, drug usage and drug availability, moving in identical directions and differing by identical amounts.

Factor	Drug Usage and Drug Availability					
	0	20	40	60	80	100
American Image	90	83	78	47	38	9
Tourism	89	90	74	29	30	29
Drug Usage	44	47	50	55	56	60
Drug Availability	23	30	34	41	45	57
Treatment Centers	11	16	33	55	76	90
Economic Productivity	90	74	40	20	14	9

Table 6.3

Table 6.3, again, mirrors results comparable to Table 6.1 and Table 6.2. These results strongly suggest that, in order to decrease the negative impact of drugs in this country, either a decrease in drug usage or a decrease in drug availability is perhaps sufficient to stem the tide in our favor. In other words, we do not need a decrease in both drug use and drug availability to improve the situation.

6.4 Effects of American Police Interdiction

Next, a series of simulations via Table 6.4 are conducted to gauge the effect of police interdiction on the drug addiction problem in America. First, simulations are run for variations on the level of American police interdiction.

Factor	American Police Interdiction					
	0	20	40	60	80	100
American Image	12	39	53	80	85	91
Tourism	30	31	32	76	88	91
Drug Usage	61	52	45	38	30	25
Drug Availability	54	48	42	35	28	20
Treatment Centers	90	82	70	55	30	15
Economic Productivity	10	15	21	42	75	90

Table 6.4

As can be seen from Table 6.4, America's image, tourism, and economic productivity increase as American police interdiction increases. On the other hand, there is an inverse relationship between American interdiction and drug usage, drug availability, and treatment centers: as the former increases, the latter factors decrease.

Figure 6.5 Effects of International Police Interdiction

The next table below, Table 6.5, focuses on the effect of variations of international police interdiction on drug addiction in America.

Factor	International Police Interdiction					
	0	20	40	60	80	100
American Image	11	38	53	79	83	90
Tourism	29	31	32	75	86	90
Drug Usage	60	55	50	42	34	27
Drug Availability	53	48	43	39	35	22
Treatment Centers	90	80	72	57	33	17
Economic Productivity	10	14	20	42	74	89

Table 6.5

The results of Table 6.5 reflect similar results obtained in the previous table: an increase of police interdiction at the international level also increases America's image, tourism, and economic productivity. In addition, an inverse relationship also exists between international police interdiction and drug usage, drug availability, and treatment centers, i.e., as the former increases, the latter factors decrease.

Step 7: Modifying the Fuzzy Cognitive Map

This hypothetical fuzzy cognitive map has included factors and relationships employed in the preceding sections to represent only one of numerous possible perceptions of drug addiction in America. It is certainly conceivable that someone else could generate a different fuzzy cognitive map.

That having been said, the current map has succeeded especially in substantially diminishing drug usage and drug availability, the primary goal for this exercise. As a result, achievement of the primary goal of this exercise obviates the need for any modifications to this hypothetical fuzzy cognitive map and additional simulations.

Step 8: Simulating the Modified Fuzzy Cognitive Map

Given that the primary goal for this exercise was achieved via the selected simulations of the factors and relationships, no simulations will be needed for a modified fuzzy cognitive map. Instead, the conclusions reached from these simulations will be discussed in the ninth and final section.

Step 9: Conclusions

Several conclusions can be drawn from the results derived from the previously obtained simulations. The first and most important one is that neither drug usage nor drug availability can be totally eliminated, at least not based on the relationships between the current selections of factors in the fuzzy cognitive map. Nonetheless, the results obtained from the simulations can conceivably reduce the level of drug addiction and drug availability, while simultaneously reducing and increasing other factors. The prerequisite steps essential for achieving this are enumerated below. The data between square brackets are selected to justify each step.

1. Vigilant American police interdiction, supported with appropriate budgetary allocations, is essential for substantially reducing both drug usage and drug availability [Table 6.4].
2. Vigilant international police interdiction is also essential for making substantial inroads in reducing drug usage and drug availability in America [Table 6.5].
3. The need for treatment centers can be significantly reduced with vigilant American and international police interdiction [Tables 6.4 and 6.5.].
4. Economic productivity can increase and improve enormously with police interdiction and a reduction in drug usage and drug availability [Tables 6.1, 6.2, 6.3, 6.4, and 6.5].
5. Tourism can also improve immensely with police interdiction and a reduction in drug usage and drug availability [Tables 6.1, 6.3, 6.3, 6.4, and 6.5].
6. America's image abroad, backed by effective police interdiction, can improve very much with a sizeable reduction in drug usage and drug availability because it reflects a safer environment [Tables 6.1, 6.2, 6.3, 6.4 and 6.5].

The results of this hypothetical fuzzy cognitive map reflect, to be sure, only one of numerous possible views of drug addiction in America. The map's relationships could certainly have been rearranged, and additional factors could be included, such as governmentally supported federal programs to educate youth on the problems of drug addiction, drug cartels, profits, and corruption. In the last section, implications for using fuzzy cognitive maps for interdisciplinary reading are discussed.

Implications for Interdisciplinary Reading

Although FCMs have been and continue to be used extensively for planning and decision-making in numerous fields (Stylios, C.D., Georgopoulos, V.C., & Groumpos, P.P., n.d.), especially in the physical and social sciences, their relevance could realistically be integrated in interdisciplinary reading assignments that either focus on a specific content area or that cut across more than one discipline. For example, students, at least those at the secondary level, could be taught to incorporate FCMs when reading topics that focus primarily in the sciences (e.g., global warming, acid rain, salmonella and E.coli poisoning, various experiments on topics in chemistry, biology, and physics, and epidemics due to AIDS, the flu, and Ebola), or primarily in the social sciences (e.g., the Middle East crisis, the current oil crisis, international relations, economic recessions, political elections at all governmental levels, the American Civil War, the Great Depression, or revolutions for liberty in America, France, and Russia), or primarily in literature, art, and music (e.g., ethical, religious, moral, and philosophical issues stemming from different countries' major novels, poetry, paintings, sculpture, or musical compositions), or in mathematics (e.g., methods for teaching proofs, or the utility of algorithms and heuristics). There certainly are several suggested topics stated above that actually cut across at least two, and conceivably three, disciplines because some problems simply do not fit tightly into only one discipline.

In utilizing FCMs in school settings, it should be stressed that having groups of students articulate their rationale for selecting specific factors or concepts for their chosen topic or problem, determining the causal relations amongst these factors or concepts, and assigning weights to the factors or concepts are what matter most in having them engage in these exercises. It is precisely the need to articulate their choices that enhances both their understanding of the class material in terms of breadth and depth and their ability to recall said material. Since learning entails both comprehension and recall, FCMs clearly have a role in molding our students into independent problem-solving thinkers, a critical attribute needed for successful competition in today's global economies.

References

Aspuru, G.O. (n.d.). *Fuzzy cognitive maps: The Middle East.* Retrieved March 15, 2008, from http://www.ochoadeaspuru.com/fuzcogmap/middleeast.php

Axelrod, R. (1976). *Structure of decision: The cognitive maps of political elites*. Princeton, NJ: Princeton University Press.

Brubaker, D. (1996, April 11). Fuzzy cognitive maps. *EDN*, 209.

Fons, S., Achari, G., & Ross, T.J. (2003, August). Analyses of the environmental impacts of an eco- industrial park using fuzzy cognitive maps. Proceedings at the IEEE International Conference, Indiana. *Industrial Informatics, 21*(24), 345 – 350.

Kosko, B. (1986). Fuzzy cognitive maps. *International Journal of Man-Machines Studies, (24),* 65-75.

Kosko, B. (1992). *Neural networks and fuzzy systems: A dynamical approach to machine intelligence*. Englewood Cliffs, NJ: Prentice-Hall.

Kosko, B. (1993). *Fuzzy thinking: The new science of fuzzy logic*. New York: Hyperion.

Stylios, C.D., Georgopoulos, V.C., & Groumpos, P.P. (n.d.). Retrieved March 20, 2008, from http://med.ee.nd.edu/MED5-1997/PAPERS/067/067.PDF

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