동태적 인과관계 모형의 설정에 대한 System Dynamics 접근법의 적용
-- 성취동기현상을 중심으로 --

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모든 사회현상의 본질이 그러하듯 조직행동론의 본질적 특성은 동태적(dynamic)이라는 점이다. 따라서 최근 많은 이론들 또는 개념모형들이 체계론적 접근방법(Systems Approach)에 근거하여 조직행동의 현상을 동태적으로 설명하고(explain) 예측하려는(predict) 시도를 하고 있다. 그 대표적인 관점이 바로 시스템의『피드백』과정에 기초한 조직(또는 조직내의 개인 및 소집단등) 행동의 균형(equilibrium or steady state)을 설명하려는 견해이다.

그러나 이론적으로 또는 개념적으로는 동태적인 특성을 가정하고 있으면서도 이러한 가정들을 체계적으로 검증할 연구 방법론은 매우 제한되어 있다. 특히 과거 2-30년간 논리실증주의(Logical positivism)의 거센 물결로 인해 이론 또는 모형의 설정이 실증적 자료와 이에 대한 계량적 분석에 따라야만 그 타당성(Validity)을 인정받을 수 있었던 학문적 경향이 강하였다. 따라서 종단적 자료(Cross-sectional data)에 입각한 정태적인(Static) 통계분석의 결과로부터 추측적인(Speculature) 추론(inference)을 통해 모형의(또는 현상의) 동태적 특성을 기술(describe)하여 왔다. 이는 물론 부분에 대한 정밀한 분석을 가능케하여 주지만, 이 방법만이 유일한 이론설정방법이라고 주장하는 것은 현상전체의 동태적 본질(on-going phenomena)을 도외시하는 학문적 편협성을 드러내는 것이라고 보겠다.

최근 몇몇 학자들이 현상을 설명해 주는 모형의 설정(Modeling)과 모형검증(Model-testing)에 대한 새로운 방법론의 필요성을 강조해오고 있다. 그 예로 통계적 분석에 있어서는 Longitudinal Studies 또는 Path analysis 등의 사용이 빈번해 지고 있으며, 특히 최근 LISREL에 기초한 인과관계모형의 설정방법을 응용하고 있다. 그러나 이보도 더욱 동태적인 관점에서 시스템의 피드백과정을 체계적으로 분석할 수 있는 방법인 『시스템 다이나믹스』(System Dynamics) 접근방법이 많은 사회과학 분야들에서 활용되어 왔다. 이 접근방법은 MIT공대의 Forrester를 비롯한 그의 동료들에 의해 세계경제모형(World Dynamics), 산업모형(Industrial Dynamics:실제는 재고관리모형임), 그밖에 기업정책 및 도시계획(Corporate Planning & Urban Planning) 등에 필요한 모형들을 정립하는데 응용이 되고 있으며, 최근 이러한 방법을 조직행동(개인, 소집단 및 조직의 행위)의 제 현상을 체계적으로 분석하는데에도 응용하려는 시도들이 행하여지고 있다.

이와같은 맥락에서 필자는 특히 개인의 작업성취동기현상에 대하여 『시스템 다이나믹스』접근방법을 적용하여 이의 인과관계를 설명하고 예측할 수 있는 동태적 모형을 정립 및 검증(Modeling & Testing)하려는 노력을 수 년간 행하여 왔다. 이러한 노력은 조직행동분야의 개인수준뿐만 아니라 소집단, 더 나아가서는 조직전체의 행동에 대한 동태적 분석을 가능케하는 결과를 가져왔으며, 또한 앞으로의 조직행동연구뿐만 아니라 여타의 인간적 요소가 관련된 사회현상의 동태적분석에로 응용이 가능하다는 점을 시사해주고 있다.

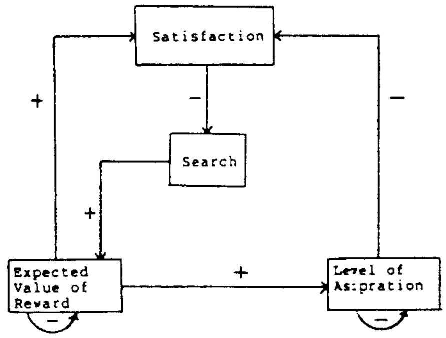

Fig. 1. General model of adaptive motivated behavior.

System Dynamics: A Methodology for Testing Dynamic Behavioral Hypotheses

TAE-WON SOHN AND JULIUS SURKIS

Abstract—**The use of system dynamics as a methodology for modelling and testing dynamic behavioral hypotheses in organizational behavioral studies is presented. The system dynamics equivalent of March and Simon's motivation model is constructed to study its behavioral consequences. The dynamic behavior obtained from this approach is identical to the analytical solution of the system of differential equations given in March and Simon's mathematical model. Three distinctive patterns of system behavior emerge from the numerous experiments conducted with the model. Experimental results leading to these patterns and additional results concerning the time to reach equilibrium and levels for the satisfaction variable are discussed.**

I. Introduction

Contemporary motivation theories attempt to explore the relationship between satisfaction and performance. The literature is diverse and consists of subtheories such as expectancy theory, goal-setting theory, equity theory, need–satisfaction theory, and reinforcement theory. Unfortunately, it is very difficult to synthesize these theories into a coherent framework because, as Schwab and Cummings [7] indicate, "there are few commonly defined constructs across the various theories" that make rigorous comparison and evaluation difficult. The same authors as well as others (e.g., Brayfield and Crockett [1]) also indicate the lack of clear definition of major variables such as satisfaction.

Nevertheless, the various theories of motivation mentioned above have helped to foster a better understanding of motivation phenomena by empirical statistical studies and theoretical hypotheses. The empirical studies collect data at a point in time or during an interval of time to examine relationships between selected variables. Then a hypothesis is structured for the behavior of the model based on the relationships between variables. The model structure is an extrapolation of the "static" statistical inferences without the means to verify or quantify the hypothesized model behavior and variable interactions over time. An example of this type of hypothesizing from the motivation theory literature would be the following [7, p. 415]:

> Triandis hypothesized that organizational pressure for high production influences both satisfaction and performance, but not in the same fashion. As pressure increases, job satisfaction is hypothesized to decrease irrespective of the concomitant variation in performance. Employee performance, alternatively, is hypothesized to be curvilinearly related to production pressure.

Some researchers have expanded these verbal definitions with a model flowchart such as March and Simon [3] and Porter and Lawler [4]. In particular, the March–Simon model also has provided a mathematical model. This model gives a multivariate framework for understanding the dynamic nature of work motivation processes. It includes the variables of what initiates, directs, and sustains an individual's motivation to produce. In fact, the March–Simon motivation model is one of "a few commonly defined constructs" that encompasses concepts of major motivation theories such as need, expectation, behavior (or action), goal, and even feedback embedded in the systems perspective. This model is often quoted in the literature. However, the multivariate character and the dynamic behavior of the model have not been discussed in detail mainly due to the lack of a proper methodology.

We will analyze the March–Simon model using system dynamics to illustrate a prototype methodology for the modelling and testing of dynamic behavioral hypotheses.

II. The March–Simon Model

March and Simon [3, pp. 48–50] suggest a general dynamic model of the individual motivation process (See Fig. 1). The model is based on the following five propositions:

1) the lower the satisfaction of the organism, the more search for alternative programs it will undertake,
2) the more search, the higher the expected value of reward,
3) the higher the expected value of reward, the higher the satisfaction,
4) the higher the expected value of reward, the higher the level of aspiration of the organism, and
5) the higher the level of aspiration, the lower the satisfaction.

Furthermore, these propositions were embodied in the following

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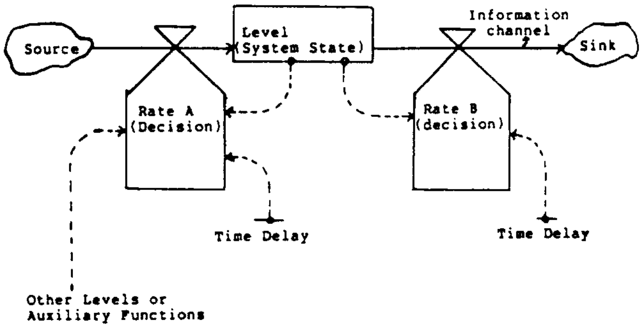

Fig. 2. An example of flow diagram.

mathematical model:

$$\frac{dA}{dt} = \alpha(R - A + a), \qquad a > 0, \alpha > 0 \tag{1}$$

$$S = R - A \tag{2}$$

$$L = \beta(\bar{S} - S), \qquad \bar{S} > 0, \beta > 0 \tag{3}$$

$$\frac{dR}{dt} = \gamma(L - b - cR), \qquad \gamma > 0, b >= 0, c > 0 \tag{4}$$

where S, A, L, R, and $\bar{S}$ denote satisfaction, aspiration, search, expected value of reward, and the desired level of satisfaction, respectively.

March and Simon have posited that the aspiration level exceed the reward level at an equilibrium because a is positive in (1). They also postulated that the search for increased satisfaction would cease at a desired level of satisfaction $\bar{S}$ in (3). Finally, they have assumed that a certain amount of search $(b + cR)$ is required to maintain the current level of reward R. Based upon these postulates, they have asserted that the system of such a dynamic process reaches a stable equilibrium.

The system of differential equations would have to be solved to see how the model behaves in the transient state, when and if it reaches equilibrium. We give the solution to the system of differential equations and also provide a system dynamics modelling approach which is an alternative to the "exact" solution of systems of differential equations. It will be shown that a properly constructed system dynamics model is equivalent to the March–Simon differential equation model. First, we present a brief introduction to system dynamics.

III. System Dynamics

The analysis of complex systems consisting of many interrelated and interactive components was made possible by several developments; feedback-control theory, large-scale digital computers, sophisticated simulation languages, and a better understanding of decision making processes.

System dynamics was developed by J. W. Forrester [2] and his group at M.I.T. [5], [6] in the late fifties and early sixties. System dynamics is a quantitative methodology based on a general systems approach. It helps construct a causal-loop theory of system behavior in terms of feedback linkages. It also deals with the dynamic processes of a complex system based upon information processing theory. Furthermore, system dynamics provides an experimental tool (simulation modelling) to analyze the dynamic behavior of a system. This methodology has been widely used in the areas of production planning, urban planning, economic planning, and corporate policy studies. However, the value

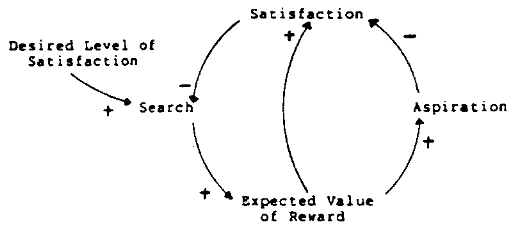

Fig. 3. Causal-loop diagram of the March–Simon model [3, p. 49].

of this methodology to analyze the dynamic behavior of a system has not been fully recognized in organizational behavior studies. Theoretical fundamentals of system dynamics associated with various paradigms in organizational behavior studies have been discussed in detail elsewhere [8]. (In [8] the authors discuss the concepts and details of constructing a system dynamics model as well.) Here, we will briefly outline the key concepts of system dynamics.

System dynamics analyzes a system in terms of cause and effect relationships by positive and negative feedback loops. This is an interim phase in the quantitative conceptualization of the system. (The concept of feedback loops has been used qualitatively in the behavioral literature by Weick [9].) This is followed by a more precise flow diagram which describes the system in terms of two fundamental components: system states and system activities. The states of a system represent the values of system variables at points in time and these values may change as a result of activities and decisions during some time period. Information on the state of the system may be fed back and used to change future activities and decisions. In the framework of system dynamics states are represented by *levels*, whereas activities or decisions are represented by *rates*. In psychological terms certain cognitive states such as memory, perceptions, or attitudes can be regarded as levels. Whereas forces or actions to change these cognitive states such as learning, comparing, or adapting can be regarded as rates.

The level is the present value of a variable that results from the accumulated difference between inflows and outflows of rates. The rate corresponds to an activity, which is the present flow between levels in the system. For instance, a current level of memory is an accumulated state resulting from the difference between a learning rate and a forgetting rate. A rate is determined by the levels of the system according to relationships indicated by the decision functions that define a rate. In turn, the rate determines the level. The rate is often determined by auxiliary functions derived from levels or from exogeneous variables. The decision function is a statement that determines how the available information about the level leads to the decision that

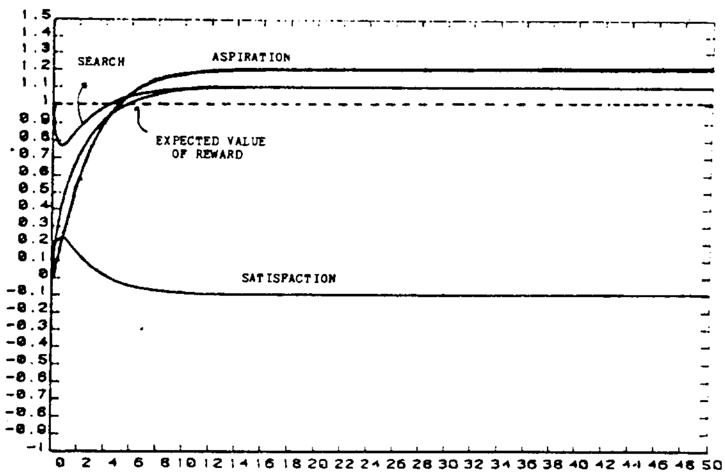

Fig. 4. Output of the analytical solution.

may influence the level. It is called a rate equation. An information channel is the connection between a decision function and a level.

One important factor to be included in the model is the time delay. The model should permit time delays "to be presented both in average duration and in transient characteristics, in close agreement with our knowledge of how the delays are actually created" [2, p. 62]. Fig. 2 is an example of a flow diagram with key concepts.

Technically, all components of the model can be expressed by mathematical equations. For example, a level equation is

$$\text{level}(t) = \text{level}(t-1) + (\Delta t)(\text{rate}A - \text{rate}B).$$

This equation represents the accumulation of a level variable at a particular point in time t. Additional values of a level are recalculated at intervals (Δt) over time. It is clear that the smaller the time interval, the more precisely the level can be monitored.

The causal-loop diagram of the March–Simon model is given in Fig. 3. The flow diagram based on this causal-loop model is given in the Appendix (see Fig. 15). The detailed flow diagram is then translated into a set of equations that can be interpreted by Dynamo, a specialized computer simulation language. Dynamo is a simulation language that provides a view of the feedback system described by equations as if it were continuous over time. This is accomplished by examining the system at (Δt) intervals of time. (The smaller the (Δt), the more precise a view we get of the dynamic behavior of the system.) Dynamo provides both numeric and graphic output on all the system elements. System equations of the model are given in the Appendix (Fig. 16).

IV. Validation of the System Dynamics Approach

Before performing various simulation experiments with the March–Simon motivation model, we provide a validation of the methodology. First, March and Simon's mathematical model is solved analytically (given in the Appendix). With the assignment of parameter values as given in the Appendix, a specific function for each system variable is derived in terms of time t as follows:

$$R(t) = -.8407 \cdot e^{-.38195 \cdot (t)} - .2593 \cdot e^{-2.61805 \cdot (t)} + 1.1 \quad (5)$$

$$A(t) = -1.3603 \cdot e^{-.38195 \cdot (t)} + .1603 \cdot e^{-2.61805 \cdot (t)} + 1.2 \quad (6)$$

$$S(t) = .5196 \cdot e^{-.38195 \cdot (t)} - .4196 \cdot e^{-2.61805 \cdot (t)} - .1 \quad (7)$$

$$L(t) = -.5196 \cdot e^{-.38195 \cdot (t)} + .4196 \cdot e^{-2.61805 \cdot (t)} + 1.1 \quad (8)$$

where $R(t)$, $A(t)$, $S(t)$, and $L(t)$ are the time related functions for expected value of reward, aspiration, satisfaction, and search activity, respectively.

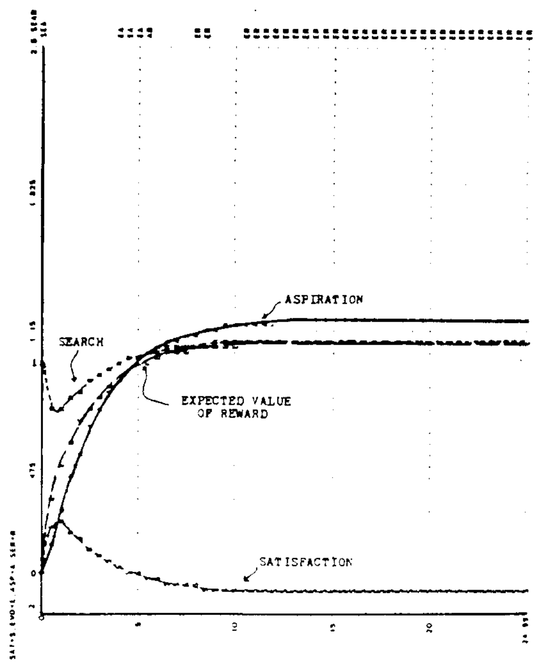

Fig. 5. Basic model output.

These functions are plotted using a Fortran function generation program. Fig. 4 is the output of the above functions.

Second, with the same parameter values used in the solution of the differential equations, the system dynamics version of the March–Simon model is run. The output is shown in the Fig. 5.

The two outputs clearly show the identical system behavior of the model through time. (Technical differences of plotting scales are due to the usage of different plotting routines.) The fact that the two solutions are identical should not come as a surprise. Dynamo's central function is to solve sets of simultaneous dif-

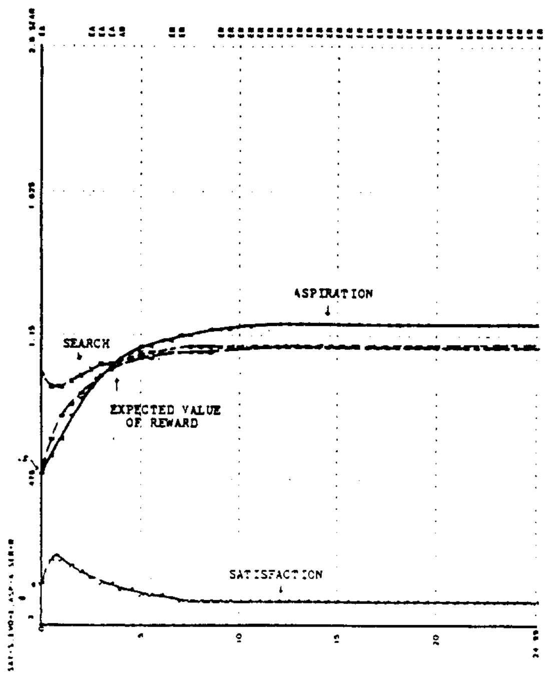

Fig. 6. Output from different initial value.

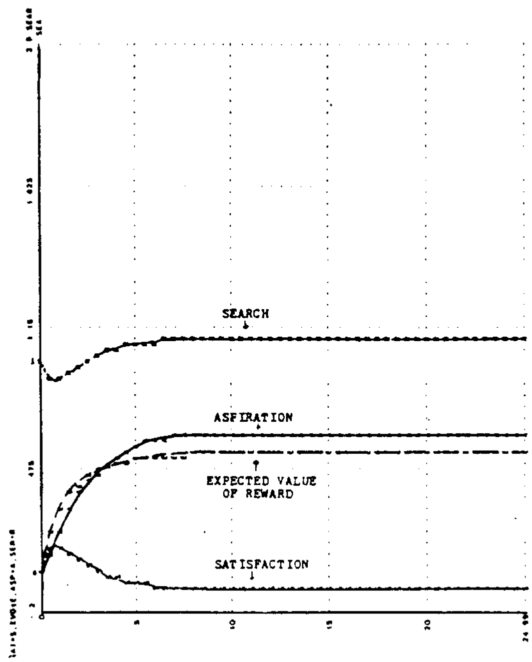

Fig. 7. Output with $\gamma = .5$ (lower expected value of reward).

ference equations. The task for the model builder is to translate or quantify the system entities properly. Thus we can conclude that the March–Simon model was properly modeled in terms of system dynamics.

It is also clear that as one considers more complex feedback systems, formulating and solving the system of differential equations become more difficult. However, the construction and solution of a system dynamics model of a complex behavioral system need not require the same degree of mathematical agility required by the formulation and solution of differential equations.

Since we are simulating a system, the results are particular to the set of parameters used. Thus one would have to solve the system for various parameter values in order to gain an understanding of the system under different conditions.

V. Model Experimentation

Having demonstrated the equivalence of the system dynamics model to the original model formulation, we now explore the behavior of the system under different parameter settings. The summary of parameter values used in the indicated experiments of the model is given in the Appendix. We will use the settings that result in Fig. 5 as the basic model output for comparison purposes.

The basic output shows that the system does reach a steady state as March and Simon indicate. Furthermore, the output clearly shows us the transient behavior of each variable before reaching equilibrium. The transient mode of the total system as represented by the system variables is the dynamic process of motivation that March and Simon have stated verbally.

In order to prove the robustness of the model, the basic model was tested with different initial values of the variables using the parameter settings of the base case. Fig. 6 is an example of one of these experiments with initial values of $R = .5$ and $A = .5$. These experiments show that the system reaches the same levels of steady state, but with a different transient behavioral processes. It can be concluded that the system reaches the same steady state, no matter what initial values are assigned to the model. Hence, we can state that the March–Simon model is robust in this sense.

Next, the model was tested with different parameter values having various behavioral implications.

Fig. 7 is the output resulting from the case where a lower parameter value for $\gamma = .5$, where γ is the coefficient related to the inflow rate of reward, is used as compared to that of the basic model ($\gamma = 1$). This can be viewed as representing behavior with a lower expected value of reward. The output shows a different motivation behavior from that of the basic model output (Fig. 5). Before the system reaches equilibrium, a lower satisfaction peak results as compared to that of the basic case. This is due to a lower expected value of reward (EVR). One can interpret this case as the behavior of a person who anticipates (or actually receives) a smaller reward from the same amount of search (or effort) thus experiencing lower satisfaction (SAT).

At equilibrium, EVR and aspiration (ASP) reach lower levels than those in the basic case. However, search (SER) and SAT reach the same levels as those in the basic case. The reason for this is that the model assumes the same goal level of DSAT (desired level of satisfaction) as the basic model does. Thus the discrepancy between the dissatisfaction (due to the higher ASP) and the DSAT sustains the search at the same level in equilibrium. This is what Schwab and Cummings [7] verbally state as to the "need-deprivation" assumption underlying the March–Simon model.

Fig. 8 is an output where a lower parameter value of ($c = .5$) is used as compared to that of the basic model ($c = 1$). As shown in (4) in the mathematical model, c represents the outflow rate of the expected value of reward. Decreasing the value of c implies a higher level of expected value of reward than that of the basic model, due to the reduction in the outflow rate of the expected value of reward. A person who anticipates (or actually receives) higher rewards from the same amount of search (or effort) feels greater satisfaction. At equilibrium, however, SER and SAT reach the same levels as Figs. 5 and 7. The reasons for this are the same as those discussed above regarding the output in Fig. 7.

Fig. 9 shows the output with a lower parameter value of ($\beta = .5$). The basic model parameter value was ($\beta = 1$). Since β

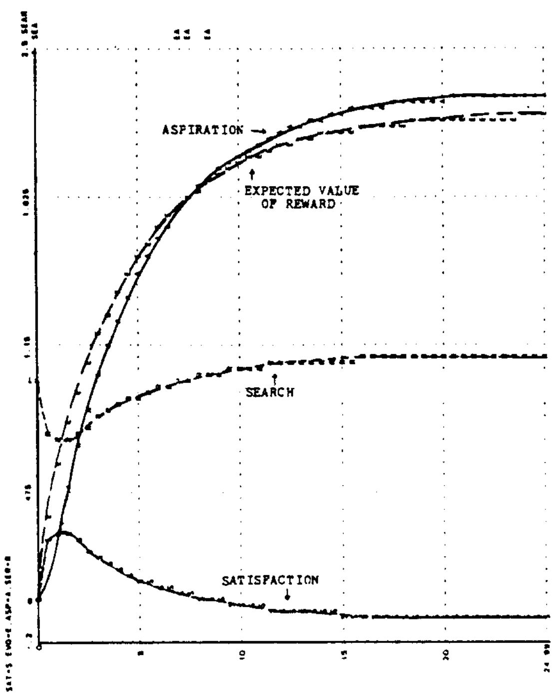

Fig. 8. Output with $\varphi = .5$ (higher expected value of reward).

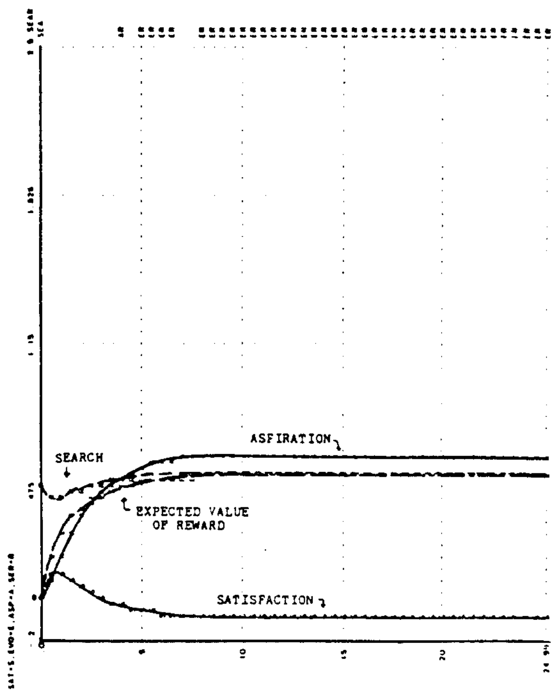

Fig. 9. Output with $\omega = .5$ (lower intensity of search).

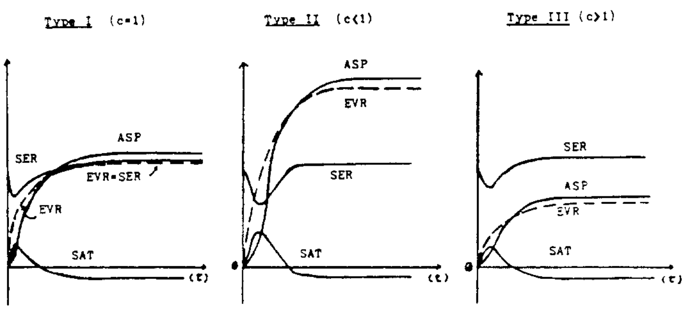

Fig. 10. Three types of system behavior.

is a coefficient related to the intensity of search, this change implies that the search rate will be less than that of the basic model. Thus, a person who exerts less search (or effort) would anticipate or receive a smaller reward and experience a lower level of satisfaction, other things remaining the same.

From these figures, it seems clear that the SAT variable always reaches the same level at steady state (-0.1), no matter what values are assigned to other variables. This is due to the constant a in (1). (A value of .1 was assigned to a in these experiments.)

The next set of results deals with parameter settings that reveal three distinctive modes of system behavior. These will be referred to as type I, type II, and type III behavior patterns. (See Fig. 10.) The three distinctive patterns that emerge are mainly due to the coefficient c, which is related to the outflow rate of the expected value of reward (or duration of perception regarding the obtained EVR). Assuming the type I behavior pattern as a "normal" behavior case, the type II pattern can be interpreted as an "optimistic" behavior case, whereas the type III pattern can be interpreted as a "pessimistic" behavior case. That is, a person who anticipates higher value of outcome from a given level of effort can be characterized as an optimistic person, and *vice versa*.

By varying the parameter values in certain combinations, one can gain insight into two aspects of system behavior: 1) the time to reach equilibrium and 2) the highest peak of the satisfaction level.

In summary, the system behaves as follows (see Table I):

1) The higher the EVR (e.g., γ), the higher the satisfaction level peaks and the later the system reaches equilibrium.

2) The higher the EVR (e.g., $\gamma = \gamma c$), the higher the satisfaction level peaks and the sooner the system reaches equilibrium.

3) The higher the ASP (e.g., α), the lower the satisfaction level peaks and the sooner the system reaches equilibrium.

4) The higher the intensity of SER (e.g., β), the higher the satisfaction level peaks and the later the system reaches equilibrium.

TABLE I
SYSTEM BEHAVIOR AS A FUNCTION OF VARYING PARAMETER VALUES

	Parameter Changes				Time to reach Equilibrium				SAT	Values at Equilibrium				Time for Zero SAT
	α	β	γ	γc	SAT	EVR	ASP	SER	Height	SER	EVR	ASP	SAT	(in periods)
1)	1	1	0.5	1	23	23	22	18	0.103	1.1	0.55	0.65	−0.1	2–3
	1	1	1	1	29	26	27	25	0.225	1.1	1.1	1.2	−0.1	4–5
	1	1	2	1	41	40	41	36	0.389	1.1	2.2	2.3	−0.1	7–8
2)	1	1	0.5	0.5	37	35	36	31	0.147	1.1	1.1	1.2	−0.1	4–5
	1	1	1	1	29	26	27	25	0.225	1.1	1.1	1.2	−0.1	4–5
	1	1	2	2	26	22	24	22	0.264	1.1	1.1	1.2	−0.1	3–5
3)	0.5	1	1	1	49	45	48	43	0.312	1.1	1.1	1.2	−0.1	7–8
	1	1	1	1	29	26	27	25	0.225	1.1	1.1	1.2	−0.1	4–5
	2	1	1	1	20	17	18	16	0.115	1.1	1.1	1.2	−0.1	2–3
4)	1	0.5	1	1	23	23	22	22	0.103	0.55	0.55	0.65	−0.1	2–3
	1	1	1	1	29	26	27	25	0.225	1.1	1.1	1.2	−0.1	4–5
	1	2	1	1	41	40	41	29	0.389	2.2	2.2	2.3	−0.1	7–8

The above statements demonstrate that March and Simon's mathematical model is consistent with the verbal propositions they state. Beyond that, the experiments give an indication of the time required for the system to reach a steady state.

Table I indicates which variable reaches a stable equilibrium first and which variable exerts the major influence on the pattern of system behavior. In particular, the former provides a clue for exploring the relationship between satisfaction and performance, which is search here, underlying the March–Simon model.

In every case, SER reaches equilibrium first, and SAT reaches equilibrium last: the higher the search, the higher the satisfaction level peaks and the longer the satisfaction level is sustained until it reaches equilibrium. (Also, see Fig. 11(d).) This result indicates that the March–Simon model fits into the "performance-satisfaction" theory. Schwab and Cummings [7] cautiously classify the March–Simon model as such.

Fig. 11 is based on the results given in Table I to IV focusing on the SAT level. Fig. 11(a) shows that the higher the inflow rate of EVR, the higher the SAT level peaks and the later the SAT level reaches equilibrium. In Fig. 11(b), the higher the rates are with respect to EVR (e.g., $\gamma = \gamma c$), the higher the SAT level peaks at the initial period, but this also leads the SAT level to reach equilibrium sooner. This is mainly due to the dominance of ASP. The dominant role of ASP is clearly shown in Fig. 11(c), where the higher the ASP, the lower the SAT level peaks at the initial period and the sooner the SAT level reaches equilibrium. This can be interpreted as the behavior of a person who has a higher level of aspiration and feels less satisfied given the same levels of anticipated (or actual) rewards and performance (or search). In summary, the ASP level exerts a major influence on the interactions among variables in the March–Simon model.

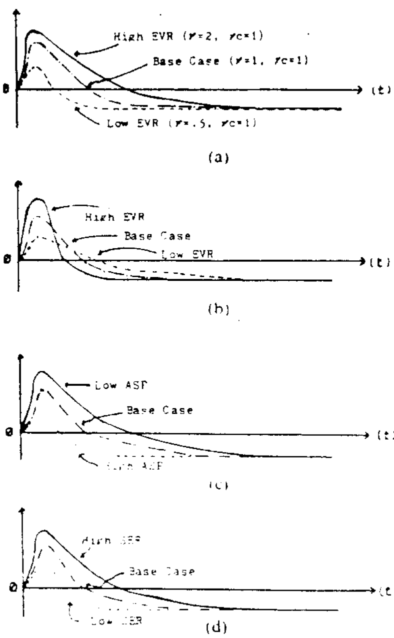

Fig. 11. Graphic illustrations of the system behavior focused on SAT. (a) SAT depending on γ (inflow rate of EVR). (b) SAT depending on various EVR ($\gamma = \gamma c$). (c) SAT depending on ASP (α). (d) SAT depending on SER (β).

So far, the experiments have strictly followed March and Simon's bounds in their mathematical model. One can explore the consequences of relaxing some of the model assumptions given in the March–Simon model. If the assumption in the equation related to aspiration is relaxed, the model may not reach a steady state. In (4), March and Simon assume that the inflow (γ) and the outflow (γc) of the expected value of reward can be different. In (1), however, they do not allow such flexibility for the rates of aspiration. If the assumption in (1) were to be relaxed similar to that of (4), it would not be a radical or "abnormal" assumption. With this relaxation, one can observe two modes of unusual behavior. Figs. 12 and 13 are the cases with lower and higher aspiration modes respectively as compared to the basic model. In Fig. 12, satisfaction reaches a positive level at equilibrium. This output represents the typical behavior of a person who has lower aspiration. Since the aspiration level is lower than the expected value of reward, given the same level of search, the person feels greater satisfaction with less search. It can be interpreted as the realistic behavior of a person who is not very ambitious. In Fig. 13 the system never reaches an equilibrium: it exhibits unlimited growth. This represents the behavior of a person who has extremely high aspirations.

In the experiments so far, the parameter values were assumed to remain constant through time. This assumption implies a deterministic behavioral pattern. In the context of system dynamics, this assumption can be relaxed and one can model probabilistic behavior over time. Fig. 14 is an illustration where the parameters are selected from specific normal distributions

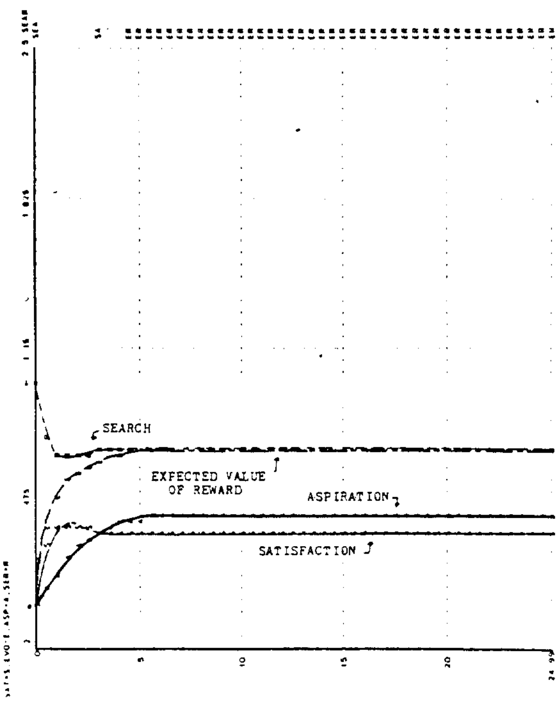

Fig. 12. Output with relaxed assumption (lower aspiration).

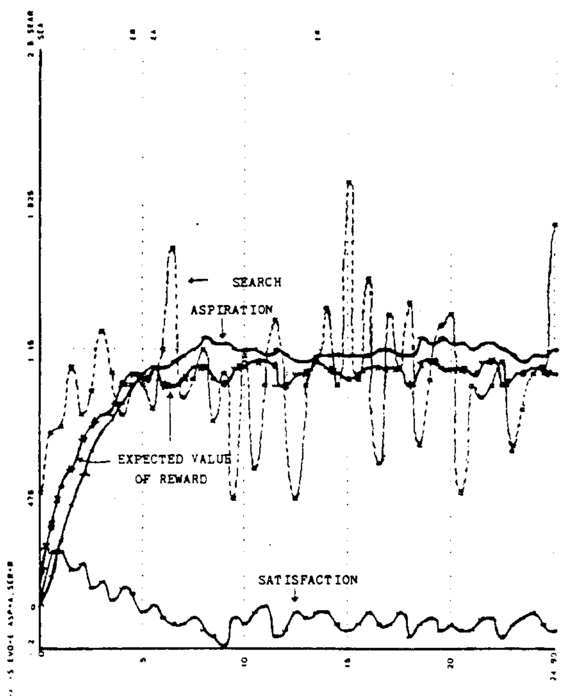

Fig. 14. Output of probabilistic model.

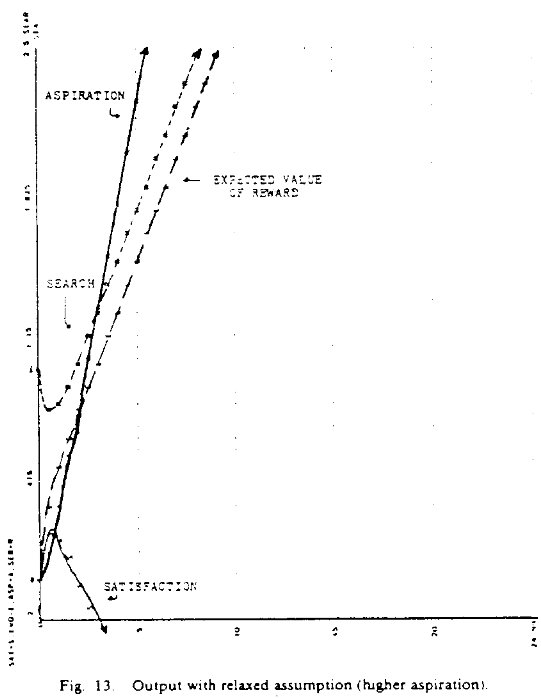

Fig. 13. Output with relaxed assumption (higher aspiration).

over time. Although the system behaves with fluctuations over time, the general shape is not different from the basic output and reaches a similar steady state.

VI. Conclusion

The purpose of this paper was to demonstrate the usefulness of the system dynamics approach as a prototype methodology to deal with the dynamic aspects of organization behavior studies. As shown, system dynamics provides an analysis of both the steady state behavior and the transient behavior of the March–Simon motivation model, which had not been attempted thus far mainly due to the lack of a relevant methodology. This methodology yields the dynamic consequences of hypotheses concerning relationships among the variables in the model. Furthermore, it does not necessarily require extensive empirical data for model construction. Rather, it may pinpoint the critical nature of certain variables prior to conducting the actual research. Empirical studies can only make inferences on subsystems or components of the larger model. There is a need to study how different inferences on "components" fit together. The system dynamics approach clearly demonstrates its great potential to deal with these unresolved issues in the current state of motivation theories as well as in other areas of organization behavior research.

Acknowledgment

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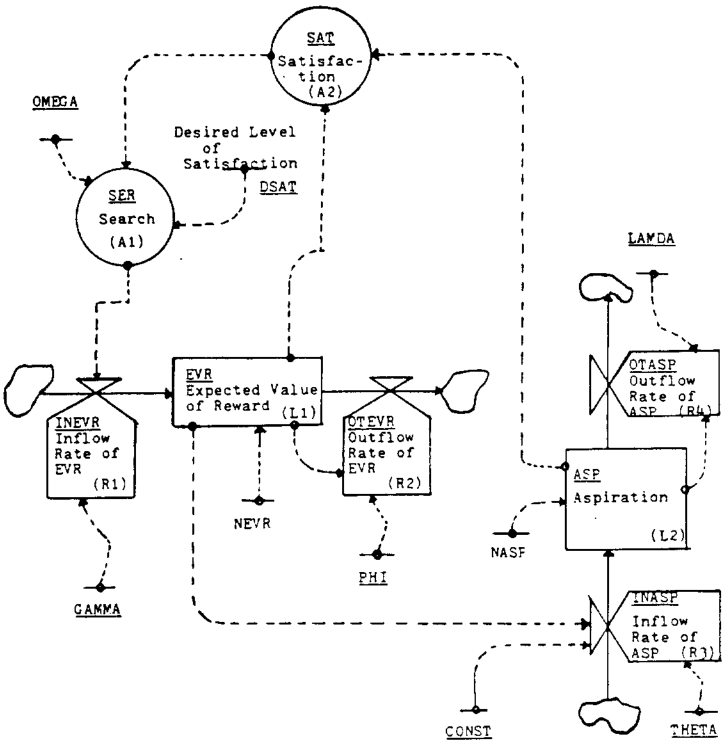

Fig. 15. Detailed flow diagram of the March–Simon model.

Appendix
The March–Simon Model

The detailed flow diagram is shown in Fig. 15. The Dynamo system equations are provided in Fig. 16.

Analytical Solution

March and Simon's model is solved analytically as follows. Given (1)–(4) replace L in (2) using (3) and (4). Thus

$$\frac{dR}{dt} = \gamma\beta A - (\gamma\beta + \gamma c) R + \gamma\beta\bar{S} - \gamma b. \tag{9}$$

Take the second derivative of (9), and replace dA/dt with (1)

$$\frac{d^2R}{dt^2} = \gamma\beta\frac{dA}{dt} - (\gamma\beta + \gamma c)\frac{dR}{dt}$$

$$= \gamma\beta\{\alpha(R - A + a)\} - (\gamma\beta + \gamma c)\frac{dR}{dt} \tag{10}$$

Replace A in (10) with rearranged (9) in terms of A

$$\frac{d^2R}{dt^2} + (\alpha + \gamma\beta + \gamma c)\frac{dR}{dt} + \alpha\gamma c R + \gamma a b - \alpha\gamma\beta\bar{S} - \alpha\gamma\beta a = 0.$$

Let $(c1) = (\alpha + \gamma\beta + \gamma c)$, $(c2) = (\alpha\gamma c R)$, $(c3) = \gamma a b - \alpha\gamma\beta\bar{S} - \alpha\gamma\beta a$. Then

$$\frac{d^2R}{dt^2} + c1\frac{dR}{dt} + c2R + c3 = 0. \tag{11}$$

From (11), the general solution for $R(t)$ is

$$R(t) = I \cdot e^{r1 \cdot t} + J \cdot e^{r2 \cdot t} - \frac{c3}{c2} \tag{12}$$

```
* MARCH AND SIMON'S MOTIVATION MODEL
NOTE
NOTE    EQUATION (2) IN THE MODEL
A       SAT.K=EVR.K-ASP.K   SATISFACTION                                (A2)
NOTE
NOTE    EQUATION (4) IN THE MODEL
NOTE
L       EVR.K=EVR.J+(DT)(INEVR.JK-OTEVR.JK) EXPECTED VALUE OF REWARD    (L1)
N       EVR=NEVR        INITIAL VALUE OF EVR                            (N1)
R       INEVR.KL=(GAMMA)(SER.K)     INFLOW RATE OF EVR                  (R5)
C       GAMMA=1                     PARAMETER OF INEVR                  (C1)
R       OTEVR.KL=(PHI)(EVR.K)      OUTFLOW RATE OF EVR                  (R1)
C       PHI=1                      PARAMETER OF OTEVR                   (C2)
NOTE
NOTE    EQUATION (3) IN THE MODEL
NOTE
A       SER.K=(OMEGA)(DSAT-SAT.K)       SEARCH ACTIVITY                 (A1)
C       OMEGA=1                          PARAMETER OF SEARCH            (C3)
C       DSAT=1          DESIRED LEVEL OF SATISFACTION                   (C4)
NOTE
NOTE    EQUATION (1) IN THE MODEL
NOTE
L       ASP.K=ASP.J+(DT)(INASP.JK-OTASP.JK)  ASPIRATION LEVEL           (L2)
N       ASP=NASP          INITIAL VALUE OF ASPIRATION                   (N2)
R       INASP.KL=(THETA)(EVR.K+CONST) INFLOW RATE OF ASPIRATION         (R3)
C       THETA=1                  INFLOWRATE OF ASPIRATION               (C5)
C       CONST=.1                      (A) IN THE MODEL FOR ASPIRATION   (C6)
R       OTASP.KL=(LAMDA)(ASP.K)  OUTFLOW RATE OF ASPIRATION             (R4)
C       LAMDA=1                       PARAMETER OF OUTFLOW RATE OF ASP  (C7)
NOTE
NOTE    INITIAL VALUES
NOTE
C       NEVR=0
C       NASP=0
NOTE
NOTE    CONTROL CARDS
NOTE
SPEC    DT=.01/LENGTH=25/PRTPER=0/PLTPER=.5
PRINT   SAT,EVR,ASP,SER
PLOT    SAT=S,EVR=E,ASP=A,SER=R(-.2,2.5)
RUN     BASIC
END
```

Fig. 16. Dynamo equations for the March–Simon model.

where

$$r1 = \frac{-c1 + \sqrt{c1^2 - 4c2}}{2}$$

and

$$r2 = \frac{-c1 - \sqrt{c1^2 - 4c2}}{2}$$

TABLE II
SUMMARY OF EXPERIMENTS WITH THE MARCH-SIMON MODEL[1]

Experiment	Theta	Lambda	Gamma	Phi	Omega	Time to reach Equilibrium	Peak of Satisfaction
Basic	1	1	1	1	1	29	0.225
1	1	1	0.5	1	1	23	0.103
3	1	1	1	1	0.5	23	0.103
4	1	1	1	1	2	41	0.389
5	1	1	1	1	4	beyond 50	0.566
6	1	1	0.5	1	2	29	0.225
7	1	1	0.5	0.5	2	49	0.295
8	0.5	0.5	2	1	1	beyond 50	0.494
9	2	2	1	1	1	20	0.115
10	2	2	1	1	0.5	17	0.025
11	1	1	2	2	1	25	0.264
12	1	1	2	1	1	41	0.389
13	1	1	1	2	1	20	0.133
14	2	2	2	2	1	16	0.139
15	2	2	2	1	1	26	0.248
16	2	2	1	2	1	13	0.041
17	1	1	2	2	2	37	0.429
18	1	1	2	1	2	beyond 50	0.566
19	1	1	1	2	2	25	0.264
20	1	1	0.5	0.5	1	37	0.147
21	1	1	4	4	1	23	0.268
22	2	2	0.5	0.5	2	35	0.173
23	2	2	1	1	2	26	0.248
24	2	2	2	2	2	21	0.283
25	2	2	4	4	2	19	0.292
26	0.5	0.5	0.5	0.5	0.5	44	0.102
27	0.5	0.5	1	1	0.5	38	0.167
28	0.5	0.5	2	2	0.5	35	0.209
30	0.5	0.5	4	4	0.5	34	0.217
31	0.5	0.5	1	1	1	49	0.312
31	2	2	1	4	1	9	0.000
33	4	4	1	4	1	5	0.000
34	2	2	0.5	1	1	17	0.026
35	4	4	0.5	1	1	14	0.000
36	1	1	1	2	0.5	17	0.046
37	1	1	1	2	4	37	0.429
38	1	1	1	4	1	14	0.000
39	1	1	1	4	2	19	0.135
40	1	1	1	4	4	24	0.268

[1] The parameters are identified as
Theta and lambda = the parameters related to aspiration
Gamma = the parameters related to the inflow of expected value of reward
Phi = the parameter related to the outflow of the reward
Omega = the parameter related to the search.
The parameters a, $\bar{S}$, and b of the model remained the same in all experiments: $a = 0.1$, $\bar{S} = 1$, and $b = 0$.

To decide the boundary conditions, let initial $R(t = 0) = 0$ and $R'(t = 0) = R1$ and er parameter values be as follows: $\bar{S} = 1$, $a = .1$, $b = 0$, $c =$ .., $\alpha = 1$, $\beta = 1$, $\gamma = 1$, and initialize $R = A = 0$. From (2)

$$\left.\frac{dR}{dt}\right|_{t=0} = R'(t = 0)$$

$$= \gamma\{L - b - cR(t = 0)\} = L.$$

From (3)

$$L = \beta(\bar{S} - S) = 1$$

$$\therefore R'(0) = R1 = 1. \qquad (13)$$

From (12)

$$R(t = 0) = R_0 = I + J - c3/c2 = 0 \qquad (14)$$

and

$$R'(t = 0) = R1 = r1 \cdot I + r2 \cdot J = 1. \qquad (15)$$

The $c2$, $c3$, $r1$, $r2$ are all known from parameter values. Hence from (14) and (15) $I = -.8407$ and $J = -.2593$. Thus

$$R(t) = -.8407 \cdot e^{r1 \cdot t} - .2593 \cdot e^{r2 \cdot t} + 1.1 \qquad (16)$$

where $r1 = -.38195$ and $r2 = -2.61805$.

From (9), we get A as follows:

$$A = \frac{1}{\gamma\beta}\left\{\frac{dR}{dt} + (\gamma\beta + \gamma c)R - \gamma\beta\bar{S} + \gamma b\right\}$$

$$= \frac{dR}{dt} + 2R - 1$$

$$\therefore A(t) = R'(t) + 2R(t) - 1. \qquad (17)$$

From (16), we get

$$A(t) = -1.3603 \cdot e^{r1 \cdot t} + .1603 \cdot e^{r2 \cdot t} + 1.2. \qquad (18)$$

From (17) and (18), $S(t)$ can be derived as follows:

$$S(t) = R(t) - A(t)$$

$$= .5196 \cdot e^{r1 \cdot t} - .4196 \cdot e^{r2 \cdot t} - .1. \qquad (19)$$