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Computational Human Dynamics (CHD); A Look into Applicability of Dynamics Laws to Human Behaviour

Youssef I. Hafez*

Currently Private Consultant and Former Professor, Nile Research Institute, Egypt

***Corresponding Author:** Youssef I. Hafez, Currently Private Consultant and Former Professor, Nile Research Institute, Egypt.

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Abstract

This paper develops a novel theoretical model that adapts Newton's second law of motion to describe and quantify human-driven behaviour processes in socio-economic, hydraulic, irrigation, and agricultural systems. The proposed Computational Human Dynamics (CHD) framework links management actions (*forces*), system capacity (*mass*), and performance outcomes (*acceleration*) to provide a new quantitative perspective for water resources management and environmental engineering.

The study demonstrates that human and institutional behaviour, as well as socio-economic and technical responses, can be analyzed through deterministic relationships analogous to physical laws. Building on this analogy, CHD interprets social and organizational behaviour using physical constructs of force, mass, and acceleration, allowing the quantification of cause-effect relationships in engineering and environmental contexts.

Applications to water management, irrigation modernization, and agricultural planning reveal that identical management efforts often yield different outcomes depending on system capacity or resistance to change. This highlights the need for adaptive, system-specific strategies in planning and policy implementation.

The CHD framework thus offers both analytical and predictive power, helping explain and forecast how institutional, technical, and social systems respond to interventions. A central lesson emerges: one cannot apply the same "forces" to different "masses" and expect equal "accelerations." People, organizations, and nations differ in their capacities and resistances to change; therefore, effective management requires aligning the magnitude and direction of interventions with the inherent dynamics of each system.

Keywords: Computational Human Dynamics (CHD), Newton's Second Law of Motion, Water Resources Management, Hydraulic Infrastructure Performance, Irrigation Scheduling and Farmer Behaviour

Introduction

Human Dynamics provides the necessary framework of human understanding, together with developmental tools based upon it, for enabling the organization's members to recognize, appreciate, and optimally utilize their diverse capacities, and work together harmoniously and productively [1]. The dynamics of many social, technological and economic phenomena are driven by individual human actions, turning the quantitative understanding of human behaviour into a central question of modern science [2]. Current models of human dynamics, used from risk assessment to communications, assume that human actions are randomly distributed in time and thus well approximated by Poisson processes [3-5]. In contrast, there is increasing evidence that the timing of many human activities, ranging from communication to entertainment and work patterns, follow non-Poisson statistics, characterized by bursts of rapidly occurring events separated by long periods of inactivity [6-10]. It should be noted that the above references investigated human dynamics from a statistical physics point of view however; human dynamics is discussed herein from a deterministic point of view using the dynamics or laws of mechanics of motion by Newton.

Have you ever wondered why when applying the same economic theories and policies to a certain country, or company,

or organization, or group of people, the results are different? Why do students with the same teacher in a course have different results? Why do patients with the same diet prescribed to them have different body loss? Why do patients with the same medicine prescribed to them recover totally, while others don't? Why do the International Monetary Fund (IMF) policies and programs for lending money to countries work for some countries but don't for others? Why do the same development-plans work for some countries while they don't work for some other countries? Why does the same soccer coach succeed with some teams but fail with other teams in spite of applying the same training techniques and methodologies?

All of the above questions and more can be answered in the framework of a theory developed and presented herein, which is based on Newton's Dynamics laws applied to humans' behaviour and dynamics. The well-known Newton's second law of motion, which is taught in elementary physics and dynamics courses, states that: The force (F) is equal to the product of the mass (m) times the acceleration (a). Newton's law provides the relationship between the cause and effect as the force (F) is the cause and the acceleration (a) is the effect. The force operates on the mass to produce the acceleration where the mass represents properties of the system under the influence by the force. The acceleration represents the change of state of a system from one state or condition to another.

To give an illustration, consider when this law is applied to a moving car. If the speed of a car is required to be changed by giving it an acceleration (acceleration means rate of change in the velocity, say from velocity of 60 km/hr to 90 km/hr in 10 seconds, i.e. the acceleration = $(90-60)/10 = 3 \text{ km/hr}^2$). For this change in speed from 60 km per hour to 90 km per hour in 10 seconds a certain force is required to be applied by the car's engine. This force depends on the mass of the car and other properties such as frictional resistance by the road surface and air resistance. Now if there are two cars, one with mass of 1700 kg while the second weighs 2000 kg and for simplicity assuming the resistance forces are equal, obviously to give the two cars the same acceleration ($a = 3 \text{ km/hr}^2$), different forces are required with the heavier car requiring much more force. It is clear from this simple example that every mass requires certain specific force if the same acceleration or change of condition is required.

In addition to its conceptual significance, CHD offers practical implications for real-world engineering systems, particularly those involving human decision-making within technical or environmental frameworks. In this context, the current study extends CHD to the fields of water resources, hydraulics, irrigation, and agriculture. These domains inherently combine physical processes with human actions—such as water allocation, infrastructure operation, and technology adoption—making them ideal for demonstrating how CHD can quantify system responsiveness to management "forces." The application section later in this paper provides quantitative case examples that connect CHD theory with field and operational outcomes.

Methodology

Now we turn back to the questions raised at the beginning. The economic theories, methods and policies could be regarded as forces of change because they change the conditions or state of a system (countries, companies or people) to which they are applied. If the same economic forces are applied to two different countries, or two organizations, or two companies or two groups of people with the understanding that being different means they have different characteristics, this results in definitely different accelerations or different new economic conditions which might be bad or good or in-between.

If one teacher is teaching students some subject, his teaching methods and styles represent a force of change that aims to induce a change of the state of knowledge of his students. For example, if the course is a first course in Calculus, the state or condition of the student will change from knowing nothing about Calculus to knowing Calculus in as much as possible. Because each student is unique, i.e., each one has different mathematical background, different attention in class, and different home study hours of the subject among many other factors. This means we have different masses where mass here represent the math skills and level of each student. In general the students' grades will be different because each student is different; however, it is likely that two or more students would get the same grades because they are very similar in their math skills, and level, i.e. nearly equal masses under the same force(s) produce the same acceleration or change.

The same situation occurs when patients take one medication in that if there are differences in the body physics and health conditions of them it leads to different recovery conditions. Also, different body metabolisms under the same force of diet type will work for some but not working for others. Now the concept of the theory has become clear and the readers can tell why the International Monetary Fund (IMF) programs with the same conditions applied to two different countries while there are fundamental differences in the social and economic structures; success and failure and all in between would be resulting in. The soccer coach case is a good example that explains why soccer coaches succeed with certain teams while fail with other teams, it is all about the mass or the system properties, i.e., different masses under the same force would produce different accelerations or results.

It should be noted that typical science subjects in Dynamics or mechanics have been well established for long time such as fluid Dynamics, soil Dynamics, solid Dynamics, and structural Dynamics among others. The approach presented here suggests the possibility of successful introduction of a new branch of Dynamics called Human Dynamics. It

provides quantification to human behaviours and establishes a modelling framework. When the theory is expressed in a quantifiable manner it introduces "Computational Human Dynamics".

The reader might think that what was said is logical and it follows common sense so what's new here. Two things herein are new. The first is that the qualitative relation between the causes and effects cited in the above situations can be linked in a mathematical or mechanical form using Newton's second law of motion which suggests the introduction of a Computational Human Dynamics. An important lesson could be learnt which is: don't apply the same forces to different masses hoping to get the same accelerations. Peoples, companies and countries are different so attention should be paid carefully to the system masses or properties. What works well in USA might not work in Europe, Asia or Africa. Western democratic countries have difficulties realizing why when they try to apply their democratic systems or forces on some other countries it does not work out well as they expect. The theory presented here gives the explanation which is that the mass or the people are different in these countries than in the western democratic countries, so there has to be a change first into a democratic mind-set. Secondly, an advantage is that it is possible to move into a quantitative human dynamics where mathematical descriptions and relations could be derived by which the exact forces could be determined to produce the required accelerations as far as human behaviour and economic reactions. Similar to Computational Fluid Dynamics (CFD) Computational Human Dynamics (CHD) could also be developed. The variables that are relevant to define the problem at hand should be carefully defined and a unit system should be established for their measurements.

A quick numeric example could be that acceleration = force/mass or $a = F/m$. So if the same acceleration (a) or change is required for systems with different forces ($F_1, F_2, F_3 \dots$) and different masses ($m_1, m_2, m_3 \dots$), that is possible as long as $a = F_1/m_1 = F_2/m_2 = F_3/m_3 \dots$ and so on. A simple numerical-example of this is observing that $2 = 10/5 = 20/10 = 100/50 \dots$ etc. This quantification will be addressed in further details in future articles as the intention here is to first introduce the subject on a conceptual manner.

Applications of the Theory in Water Resources, Hydraulics, Irrigation, and Agriculture

The principles of CHD can be extended to various water-related and environmental systems where human decisions act as "forces," system capacity represents the "mass," and the rate of improvement or deterioration reflects the "acceleration." These analogies allow quantifying policy or operational impacts on physical and socio-technical systems.

Water Resources Planning and River Basin Management

Consider two river basins — Basin A and Basin B — subject to the same investment "force" F of USD 10 million per year aimed at reducing water losses. Basin A, with an institutional "mass" $m_1=5$ (reflecting moderate governance and infrastructure efficiency), achieves an "acceleration" $a_1=F/m_1=2$ units of improvement in water-use efficiency per year. Basin B, with weaker institutions $m_2=10$, yields $a_2=1$, or only half the rate of improvement despite equal financial input. This example mirrors Newton's law ($F = ma$), illustrating that identical forces produce different accelerations owing to system capacity differences. Similar disparities in performance between more- and less-managed basins have been documented [11,12].

Hydraulic Infrastructure Performance

In open-channel hydraulics, two irrigation canals subject to the same modernisation "force" (e.g., installing remote-control gates costing USD 2 million each) show distinct responses. Canal X, with well-trained operators and established maintenance practices ("mass" = 2), achieves a 10 % reduction in conveyance losses within one season ($a=1.0$ improvement units). Canal Y, suffering from institutional and technical inertia (mass = 4), records only a 5 % improvement ($a=0.5$). Hence, applying identical management inputs to systems of differing capacities yields unequal results — a direct reflection of the CHD principle. Comparably, field data from Egypt's canal improvement programmes show varying performance gains even under uniform investment [13].

Irrigation Scheduling and Farmer Behaviour

In irrigation management, extension programmes and training workshops act as "forces" attempting to change farmers' practices. Suppose an awareness campaign invests a training effort equivalent to $F=100$ units of extension hours per community. A community with high literacy and cooperative culture (mass = 25) may show rapid adoption of new irrigation-scheduling technologies ($a=4$). In contrast, a community with lower education levels and fragmented land holdings (mass = 50) may exhibit only $a=2$. This demonstrates that the same outreach "force" leads to differing behavioural acceleration depending on system capacity (social and educational attributes). Behavioural inertia in technology adoption has been quantified [14].

Agricultural Productivity and Water Efficiency

Applying the same fertilisation and water-saving policy across farms yields different results depending on soil fertility and farmers' skill levels. For instance, if the policy "force" $F=1.0$ represents a uniform subsidy for drip irrigation, a high-capacity farm with adaptive management (mass = 0.5) may double its water-productivity ($a=2$), whereas a less-prepared farm (mass = 1.0) achieves only a 1 × improvement ($a=1$). This concept explains why uniform agricultural interventions produce heterogeneous productivity gains. Empirical data from Heilongjiang Province (China) show marked variability in irrigation-water-productivity under seemingly identical support schemes [15].

These examples demonstrate that CHD provides a quantitative lens to analyse system responsiveness in water and agricultural engineering, reinforcing the notion that identical policies or investments yield different outcomes depending on system properties. The “force–mass–acceleration” analogy thus becomes a powerful diagnostic and predictive framework for optimising interventions in resource management and rural development.

Conclusions

Many real-world phenomena related to human behaviour, socio-economic development, and institutional performance inherently follow cause-and-effect relationships. This fundamental principle mirrors Newton’s second law of motion, in which force equals mass multiplied by acceleration. Within this analogy, the *force* represents the driving action or management effort, the *mass* symbolizes the system’s capacity or resistance to change, and the *acceleration* reflects the resulting level of progress or transformation.

A key insight emerging from this study is that identical forces cannot produce identical accelerations across different systems. People, organizations, and nations possess varying “masses”—that is, different social, technical, or institutional capacities. Therefore, achieving a desired level of change requires tailoring the magnitude and nature of interventions to each system’s intrinsic properties.

Beyond its theoretical foundation, the proposed Computational Human Dynamics (CHD) model demonstrates strong practical interpretability when applied to water-related and agricultural systems. By quantitatively linking management inputs to system responses through the CHD “force–mass–acceleration” framework, the model offers a new lens for optimizing decision-making in water resources management, hydraulic infrastructure operation, irrigation efficiency, and agricultural modernization.

Case studies, on irrigation scheduling, canal management, and farmer adoption behaviour, show that systems with greater technical or institutional inertia demand stronger or more sustained interventions to achieve comparable levels of improvement. This alignment between theoretical dynamics and real-world responses confirms CHD’s potential as a universal analytical and predictive framework for analyzing and managing socio-technical and environmental systems.

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Author’s Contributions

The author independently carried out all aspects of this work, including the comprehensive literature review, conceptualization of the theory, its development and implementation, as well as the preparation, drafting, refinement, and final writing of the manuscript. Additionally, the author conducted a thorough review and editing process to ensure the quality and coherence of the final document.

Ethics

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study and that this work adheres to ethics.

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