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Decision Support

An innovative orders-of-magnitude approach to AHP-based mutli-criteria decision making: Prioritizing divergent intangible humane acts

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ABSTRACT

An innovative Analytic Hierarchy Process-based structure is developed to capture the relationship between various levels of activities contributed by people to society. Physical objects have widespread extension and degrees of importance that often differ by many orders of magnitude. Similarly, mental thoughts and criteria occur in widely heterogeneous entities that have to be sorted and arranged into homogeneous groups of few elements in each group so that one can evaluate the relationships among them accurately, from the smallest to the largest. It is through such a framework for organizing factors with smooth transition that it is possible to derive reliable priorities from expert judgments. The proposed model enables one to make decisions and allocate resources in as detailed and fine a way as possible. In addition to the traditional approach of structuring criteria into multiple clusters, the alternatives of a decision are also organized into the lowest multiple levels of that hierarchy. This arrangement and evaluation of alternatives differs from one criterion to another, which adds to the complexity of the undertaking when the alternatives are heterogeneous. The coherent approach to structuring complex decisions with the Analytic Hierarchy Process enables one to transcend the complexity of dealing in a scientific way with the problem of widespread orders of magnitude of criteria and alternatives in a complex decision. When the magnitudes are actually very small or very large, the accuracy of *rating alternatives one at a time* instead of comparing them in pairs involves much guessing, and can lead to a questionable outcome. Alternatively, comparisons, which are necessary for the measurement of intangibles, have greater and better justified accuracy.

1. Introduction

The past we inherit; the future we create, the saying goes. To create a credible future that is founded on our global values and priorities we need to learn how to deal with the immense variety of factors and with the expanse of the many dimensions of this variety. Our progress depends on our ability to make effective decisions that depend on one another in their causes and effects, on inputs and outputs and on being able to reach out to the smallest and largest causes and effects of which we are aware. Phenomena we are creating now that will have significant influence on the future are already happening. We are currently witnessing intersecting revolutions in biotechnology, nanotechnology, molecular electronics, computation, artificial intelligence, pattern recognition, virtual reality, human brain reverse engineering, brain augmentation and robotics. Undeniably, knowledge and technology have in general expanded consciousness far beyond what we could imagine only a little while ago, and such knowledge and information would ultimately alter the nature of what it means to be human.

To date our decision making has not attained its maximum potential and success, especially those decisions that require a comprehensive global view (Ozdemir and Saaty, 2006). One reason may be because such decisions are many and diverse, and are separated in time and space. Their interactions and their consequences are hard to contemplate concurrently, as exemplified by the excerpt from the Economist (Oct. 9, 2010, p. 30) with regard to the very slow recovery from the greatest economic recession since the great depression of the 1930's: "The economic case for a growth strategy that combines hefty fiscal cuts with timid structural reform is not obvious especially when private demand is likely to stay weak. In the long run bold productivity enhancing reforms would do more. . .."

The sheer volume of information on the Internet shows that we all need to accelerate the process of learning to become more creative and have courage to use our creativity in many different sometimes wild and fast moving technological ways. The renowned futurist Kurzweil (2005) writes that "technological change is exponential, contrary to the common-sense "intuitive linear"

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view. So our society won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The "returns", such as chip speed and cost-effectiveness, will also improve exponentially. There's even exponential growth in the rate of exponential growth. Within a few decades, machine intelligence is likely to surpass human intelligence, leading to The Singularity—technological change so rapid and profound it represents a rupture in the fabric of human history. The implications include the merger of biological and non-biological intelligence, immortal software-based humans, and ultra-high levels of intelligence that expand outward in the universe at the speed of light."

Knowledge in different fields must be creatively integrated and structured to facilitate making complex decisions that are interdependent (Saaty and Takizawa, 1986; Saaty, 2007). How do we prioritize the building blocks (Millet and Saaty, 2000) whose importance will vary by many orders of magnitude? *What we need is to learn about how to deal with the problem of the diversity of alternatives* (*and when needed also of criteria*) *that are too far flung to assign them numbers from a scale without a questionable outcome of priorities. We must compare them to determine their relative magnitudes. That is our concern for the rest of this paper.* The well-known hierarchical multi-criteria decision making aid—the Analytic Hierarchy Process (AHP) offers a practical tool for decision makers facing such prioritization problems. The AHP has been applied to diverse applications; see examples in Shang and Sueyoshi (1995), Sueyoshi et al. (2009), and Tjader et al. (2010). This research advances the current AHP literature (Saaty, 1996, 2003) by addressing the need of prioritizing numerous alternatives of substantial heterogeneity.

In what follows, we first discuss the need for considering many orders of magnitude difference in the priorities of decisions. Our main thrust is to develop an example based on the contribution of people to society, and on the need to reward some people with such recognition that today has no direct bearing on enhancing people's economic wellbeing. Thus developing a way to evaluate the significance of all such acts looms high in these considerations. Criteria and alternatives are identified and then integrated in the improved AHP model in which priorities are developed for all acts, whose importance is eventually separated by ten orders of magnitude.

2. Decision making using the new orders-of-magnitude AHP model

There are many factors that influence outcomes in decision making and these factors may straddle the spectrum of possibilities from the very low to the very high priorities. We often impatiently assume that we can reduce the diversity of factors into only a few—what we at a given time consider to be the important ones. But in real life, there may be numerous not-so-important determinants of an outcome, and these low-priority determinants could be collectively very influential in shaping a decision. A serious weakness in decision making to date is the mixing and reduction of all factors into few that one habitually assumes to be the important ones.

An essential difference between what we do in this paper and what one does using traditional measurement is that in the latter, in some way, a number from a scale is assigned to each element once and for all. In our case, measurements of objects are derived from gradual relative comparisons with respect to properties that can change from instant to instant as behavior often does, and also from problem to problem. Applying a once and for all measurement from a scale to properties that remain the same or about the same is justified for events in which the elements do not change their properties over time. However, this is not the way to do it in the measurement of multi-faceted (dynamic and transient) behavior. Thus unlike the use of traditional measurement, we need to derive measurements for not so durable objectives. As a consequence, solving a problem with relative measurement requires greater effort to lay out the structure and to perform relative measurement comparisons for that problem. One has to do much more thinking to make pairwise comparisons and justify that analysis than one does when one has readymade scales with arbitrary units used uniformly to measure everything. As in any physical science, the concern is that the resulting numbers do not correspond to some meaning for the contexts in which they are used, but need judgment by knowledgeable persons to interpret their significance. Interpretation of the meaning and significance of numbers is at the heart of all theories and formulas used in science. Thus science is subjective because it needs personal interpretation that also becomes group interpretation. This observation is particularly relevant for our consideration in this paper.

Because multiple factors are often inhomogeneous (Saaty, 1994a,b), it is essential to organize them carefully into different homogeneous clusters and then deal with the linkage among these clusters in the process of relating them and then deriving priorities for their measurement. As we shall see later, by using an example, we take the step to group the homogeneous activities first in separate clusters, and then prioritize them within each cluster and finally combine the different cluster measurements by using a pivot element from a cluster to an adjacent cluster. If the clusters are arranged in ascending order, when the priority derived for an element exceeds (is dominated by) the other elements by more than an order of magnitude, then that element is moved to the cluster that follows (precedes) the given cluster.

2.1. A new AHP model for comparing heterogeneous elements

Traditional multi-criteria decision making methods evaluate all alternatives in a single level, which inadvertently restricts the simultaneous comparison of numerically heterogeneous alternatives. For dealing with the comparison of homogeneous elements, it is known that one cannot usually compare more than about seven homogeneous elements without increasing the overall inconsistency of the judgments. The scale used for comparing homogeneous elements in the AHP is restricted to the absolute numbers 1–9 and their reciprocals and perturbations when evaluating the relative importance of one element against another element (Saaty 1990a,b). When one has more than seven homogenous elements to compare, one links them with a common element that is called "a pivot", and uses its measurement in both clusters to combine the measurements in the two clusters. That is also what one does to extend the use of the scale for the measurement of elements in heterogeneous clusters. By grouping alternatives into different comparison matrices and linking them through pivot alternatives, numerous alternatives in different clusters are linked together through their priorities. As a simple example we compare a cherry tomato with a watermelon according to size as in Fig. 1. We use a process of clustering with a pivot from one cluster to an adjacent cluster that is one order of magnitude larger or smaller than the given cluster, and continue to use the 1–9 scale within each cluster to make the comparisons, and in doing that, the scale is extended as far out as desired.

What determines the clusters is the proximity of the relative value of the priorities of the elements in each. Fig. 2 shows the orders-of-magnitude AHP schema produced in the process. As usual, at the top of the model it includes a goal, followed with criteria and sub-criteria. In contrast with current AHP structures, in the second half of Fig. 2, the proposed AHP schema allows for multi-cluster of alternatives. If the priority of an alternative differs by

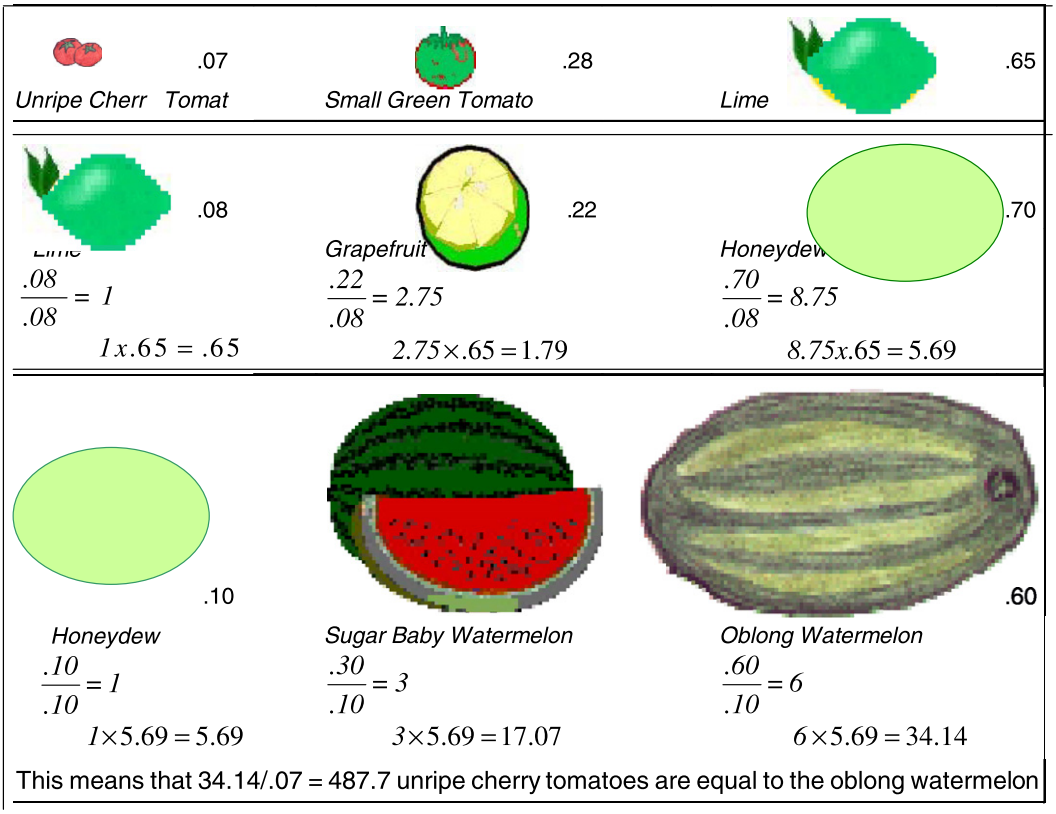


Fig. 1. Clustering to compare non-homogeneous objects.

an order of magnitude, it is moved to the appropriate cluster. To do that one simply compares it with the largest priority element in that cluster and if its priority is close in magnitude, it is kept in that cluster. Otherwise it is moved to a cluster below or above it. Note that many elements may be homogeneous but still need to be grouped in clusters to make the comparisons conform to the requirement of consistency. In general, hypothetical elements may have to be introduced to make the transition from cluster to cluster a well-designed operation. The entire process stretches the imagination to deal with magnitudes and dimensions. To address the difficulty of dealing with this subject, we elaborate the procedure of the proposed AHP model by using the example of generous and caring activities contributed by people to society. An interesting example can be found in comparing a small gesture of kindness with the large donations made by Bill Gates. To illustrate our model, we discuss the heterogeneous undertakings in the following section.

3. The importance of valuing activities contributed by people

Unemployment brings sharp decline in income and laid-off workers suffer the worst and join the ranks of the impoverished in negative economic climates. Economic suffering appears to be an inevitable consequence of economic cycles. It shows that a society focused on monetary value alone is not designed to ensure citizens' happiness; happiness is not easily pursued by those who must worry about their next meal and about paying the rent and sending children to school.

On the other hand, the unemployed have ample time and abilities to make contributions to enrich society. Society is shaped by numerous contributions and activities people make to enrich it, but currently there is a lack of an established means to recognize and include these contributions in a compensation system. Often, acts of helpfulness are rewarded with words of praise and gestures of appreciation, certificates and mementos, and sometimes with acclamation in the media. "Thank you" is often the only recognition and appreciation they receive.

Doing favors inevitably involves time and labor. Under different circumstances, such effort is compensated with money. At times, the individuals who perform acts of kindness do not need monetary payment or recognition. But more often, the person doing a worthwhile favor is not so fortunate economically. Thus, an act of kindness may provide an opportunity for compensation, either directly from others or from society. Recognition of people's good acts should put society at a higher level of sensitivity to individual needs. Many acts of kindness can be done by temporarily laid-off workers who are very eager to contribute to the society. This area of human activity has not been examined and worth study in the context of multi-criteria decision making.

3.1. Need rating intangible contribution to improve life quality

The UN Human Development Program (Gaye, 2007) reports that only half of the world's time spent on "productive activities" was reported in the GDP. Meanwhile, numerous endeavors that are critical to the survival of modern society are unpaid. When only paid work is considered "real" work, the connective tissue that holds society together—trust, reciprocity, and civic engagement—are simply unaccounted for. We believe active contributions should earn contributors a new kind of credit, translatable to satisfying their basic needs and improving their wellbeing. Recognizing and rewarding people's efforts with social units could also help society encourage more people to perform humane acts. The social units they earn might be exchanged for favors from others when the need arises. By assigning fair market values to benevolent acts, we foresee more people being motivated to contribute to society actively

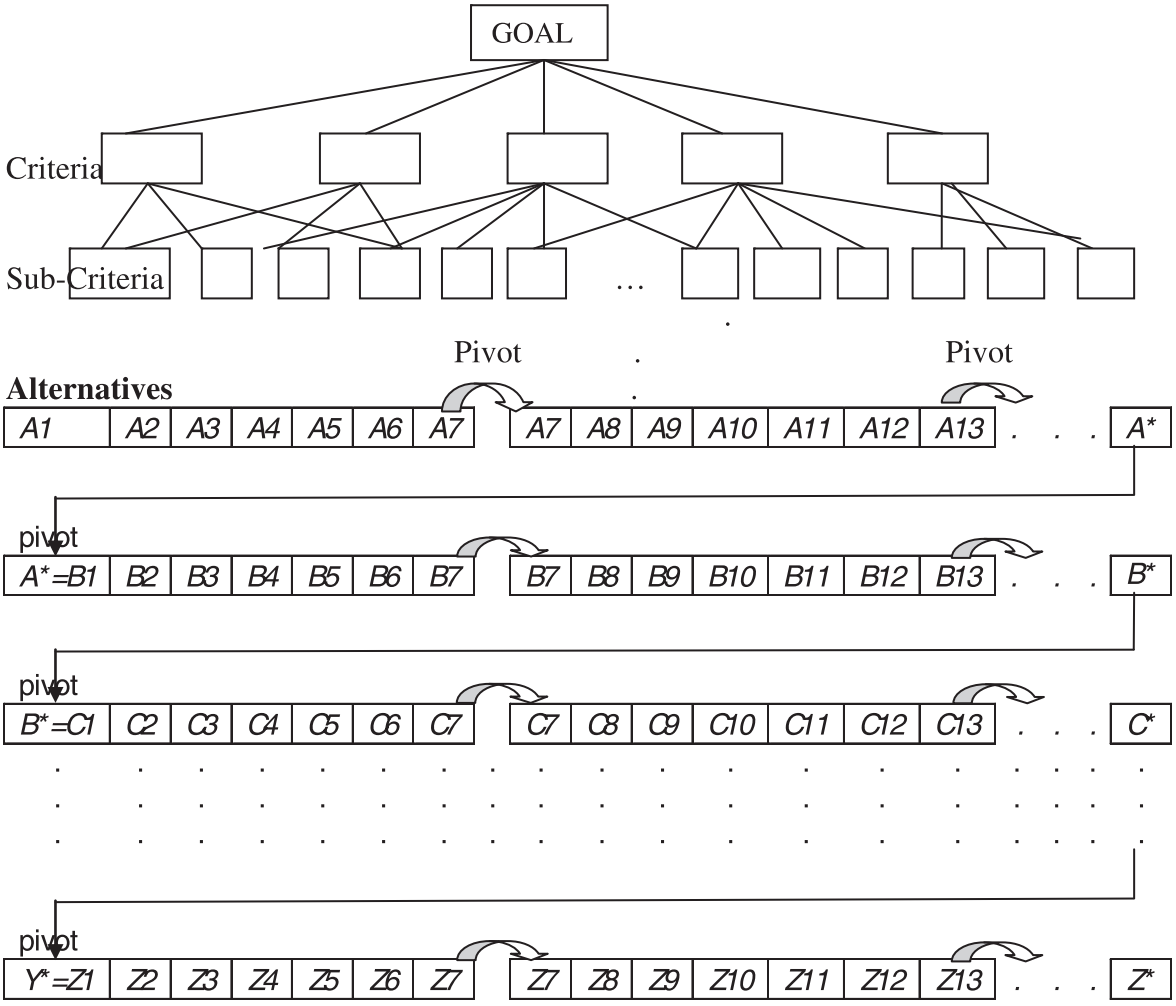


Fig. 2. The orders-of-magnitude AHP schema to mutli-criteria decision making: multi-level of criteria and sub-criteria, with multi-level of alternatives. Note: The rightmost alternative with superscript "×" is the pivot alternative, which reappears as the first alternative in the next cluster.

and more well-being created and devoted to the society. The potential monetary conversion scheme offers a promising way to motivate more people to commit and more research in this direction.

Taking the economy of large unemployment as an opportunity to develop a more compassionate society would ensure that the world functions humanely beyond money and behaves consistently with cherished principles. The new system should explicitly include normative values—family, neighborhood, community, city, country, and the entire world which drives the creation of diverse intangible values. Compensating people for contributions that are not strictly economic but humane and intangible would benefit society. The proposed model can formally prioritize all criteria and activities in a scientific and systematic way. It determines the worth of the service people offer and the potential for exchange to enrich ordinary citizens' life.

Pursuit of happiness along with life and liberty are inalienable rights. Britain is planning to introduce a "happiness index" to measure the nation's psychological and environmental wellbeing (Yahoo, 2010), and employing a happiness index for future policy-making and prepare methods to assess the "general wellbeing". Canada and France are also taking on a similar initiative. Kostigen (2009) maintains that there are various reasons for happiness: health, welfare, prosperity, leisure, family, and social connections. In this paper, we look at activities from different angles and concentrate on existing acts that increase wellbeing of others. We are now facing a choice between a society where people accept some sacrifices for the common good or a divided society where groups focusing on protecting their own interests. Appeals to the common good are frequently heard when discussing business' social responsibility, health care systems, environmental pollution, education, crime, and poverty (Velasquez et al., 1992). We believe that a community where people reach out and help each other would be a happier one.

3.2. On quantifying the relative value of altruistic acts

The idea of measuring the worth of intangible acts in relative terms is quite new. However, people's activities vary with circumstances and do not have the permanence of objects manufactured by industries that consume resources in the form of materials and overheads. Therefore, we cannot hope to ascribe to them a constant (absolute) value, as we do with objects. We can only measure them in terms relative to: similar acts with which they are compared; the amount of effort and time needed to complete them; and, perhaps the impact they produce. Thus, we need to perform comparisons with a variety of other actions to develop value permanence for acts within a group of categorized situations. The question is: how to perform comparisons to produce meaningful and useful ways to measure intangibles and convert those measurements into social units or dollars? To derive the significance (priorities) of the benefits of intangibles that are important to people, we demonstrate the order-of-magnitude AHP model in a hier-

archy where these factors are incorporated into a formal evaluation system. Our model will show that different types of service have different value. For that reason, the amount of "value" exchanged in any transaction should not be arbitrary or negotiable but carefully planned. Our model can help to (i) determine exchange standards for benevolent acts in more diverse communities where products or services may encompass a variety of skills, experience, training, equipment, or risk, and (ii) reduce uncertainty in the evaluation process and outcome.

In equilibrium, all prices are known to all traders, thus eliminating price uncertainty as a rationale for unacceptability in trade (Starr, 1972). When a society suffers from severe recession or hyperinflations, and currency is unreliable, exchange provides an acceptable alternative to increase individual and community well-being. The proposed AHP model could help provide an objective worth and a common medium of exchange to store values. When benevolent activities and random acts of kindness are acknowledged, dormant social potential is awakened for further development. Historically, the multi-criteria facets of human activities have been difficult to quantify in objective terms. Our model which allows for the exchange of intangibles (social units) in the free market may help reduce the anguish of people who have little monetary wealth. We feel that it could also raise awareness of how to live an "affluent" life without money. Another reason we must create "social units" is because some people often feel unappreciated for all that they do and may in time feel unfairly treated for all the meaningful effort they provide, if society does not get around to recognize their contributions. There is of course the danger that people may collude to earn credit in a fraudulent way. Safeguards need to be examined following better understanding of the idea and of its implementation.

Intangibles and their measurement are at the heart of all pursuit, especially socio-economic endeavors. Hubbard (2007) writes that it is important to develop a method to explain, measure, value, and manage intangibles. In the following section we explore a society's valuation system where, besides currency, people may enumerate and acquire credits for their services.

3.3. Non-monetary units already used in parts of our world

A very useful alternative for the disadvantaged is to equate people's acts into money as done in Yufuin, Japan. Yufuin has suffered economic difficulties with low-paying and seasonal tourism-related jobs. To resolve this predicament, residents print their own currency to solve a chronic yen-flow problem. Using the locally printed notes, yufu, residents enjoy their own wealth and are not subject to what the national government does. In addition the Yufu has been converted to the Yen through general agreement. Our model could give yufu scrip a publicly agreed-upon value when the pairwise comparisons are made through group decision making of that society. Residents of Yufuin could offer services to exchange for yufu freely. Villagers with little cash can trade labor for life's necessities and improve living standard (Larimer, 2006).

Another example is Local Exchange Trading Systems (LETS, 2011). LETS was established in 1983 by Michael Linton in British Columbia, Canada. It is a local, non-profit exchange network where goods and services are exchanged without using national currency. Members in LETS earn credits from any member and spend them with anyone else in the system. An individual may work on job A for person X and spend it later on job B with person Y. Under such a system, people can build houses using LETS in place of a bank mortgage, freeing owners from onerous interest payments. LETS revitalizes communities by allowing individuals, small businesses, local and voluntary groups to cooperate and to extend purchasing power. It stimulates the economies of financially depressed community that have goods and services, but scarce of currency. LETS are also present in South Africa, New Zealand, Australia, Israel, USA, Norway, United Kingdom, Europe, Japan, South Korea. The AHP model proposed in the paper could be applied to Yufuin and LETS systems to develop standards for exchange.

In short, the values of rewards are often forgotten and people have nothing tangible to show for them. By creating equivalence with money, we offer an opportunity to reward people with something tangible and useful. Clearly, Bill Gates does not need this kind of compensation, yet a dedicated, conscientious but economically poor individual may appreciate such monetary equivalence that could enhance his living style as no other kind act would do for him. This would be one instance where money is not the root of all evil, but it is the sustenance of a lot of good.

4. Identifying criteria and alternatives for the proposed AHP model

The AHP makes use of the principles of decomposition, comparative judgments, and synthesis (Saaty, 2001). Decomposition involves constructing a hierarchy which puts the goal of the problem at the top and places the criteria, sub-criteria, and alternatives at descending order of the hierarchy. For comparative judgments, a comparison matrix is arranged at each level to compare pairs of (sub)criteria or pairs of alternatives. The fundamental scale of absolute numbers used to represent dominance with regard to a common property by using pairwise comparisons ranges from 1 (indifference) to 9 (extreme importance, preference or likelihood).

The complete pairwise comparison-matrices are synthesized to estimate the relative priorities for all alternatives. In the end, the AHP provides rank order and relative value on an absolute scale for each alternative (Saaty, 2006). Conventionally, the presence of intangibles adds new dimensions of complexity to decision problems. Due to subjectivity, evaluating intangible contributions to society is a difficult task to perform. Without a systematic approach, decision makers may deal with the problem using knowledge, experience and intuition. The process may entail a level of bias, inexactness, and inconsistency. Nevertheless it must be done. A systematic way of doing the evaluation like the AHP offers a safe valuable tool to deal with qualitative and intangible issues, because it makes the problem more transparent, comprehensive and provides the means to check on each judgment and where bias may be involved.

The composite views in this paper are drawn from a three-member committee's personal observations and experience, including information from multi-media and discussions with other colleagues. The values assigned to the variables are intended to be illustrative, not final, because they need greater public participation. Still we have provided a structure with the factors and alternatives properly arranged. The judgments in the model work as a foundation, guiding the reader to recognize the value of important contributions made by people throughout the world and to understand the structure to deal with them. It is common for people to believe that in general diamonds are more valuable than water, but in particular situations where a person may die of thirst water becomes the most precious substance for life. This implicitly proves that the existing market does not necessarily reflect human value fairly—socially, ecologically, or politically because it does not include all the necessary criteria to evaluate things comprehensively. We propose a way of thinking that is different from our familiar imbalanced system—a system that is too heavily relied upon in our current society.

4.1. The evaluation criteria

People have several basic needs. In Fig. 3, we modify Maslow's (1943) hierarchy of needs to derive criteria for evaluating activities

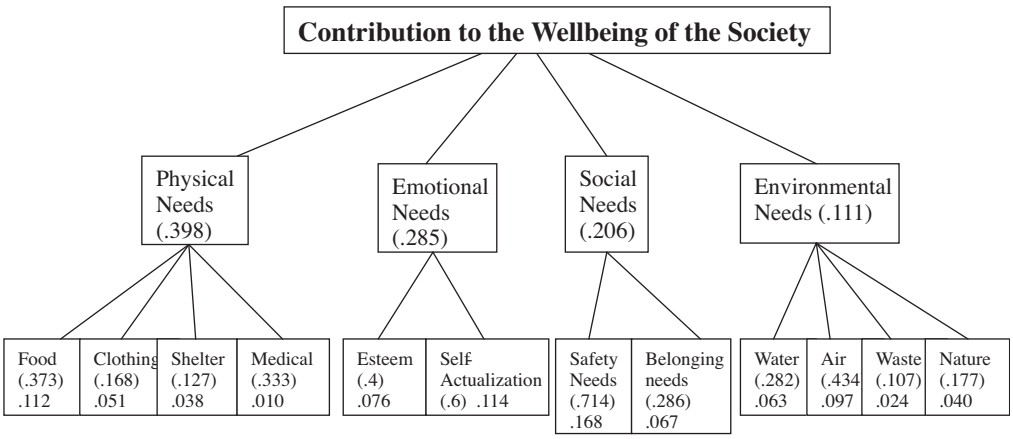


Fig. 3. The AHP criteria and sub-criteria and their corresponding weights for evaluating the contribution of the altruistic acts to the wellbeing.

through which people make a contribution. These criteria are shown in the second level of Fig. 3, and are further broken down into 12 sub-criteria, shown in the third level of the hierarchy.

Physical needs (the 1st criterion) are those necessary for maintaining body strength, including food, clothing, shelter, and medical. *Emotional needs* are the desire of people to gain respect from others and feel powerful. Through self-actualization, people achieve individual potential and operate at higher personal capacity.

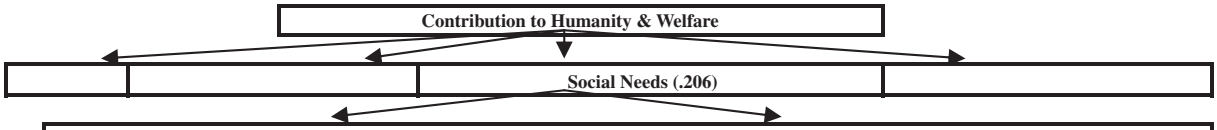
Social needs are those that make people feel safe and draw a sense of belonging. Safety keeps people from harm. A person with a strong social network and support feels safer. Belonging needs are related to affection and being a part of a group. A helpful group member feels more integrated with society. Finally, *environmental needs* center on protecting the earth and its ecosystems. This includes protecting nature to maintain fresh air, clean water, and ensuring that garbage and other wastes are removed and processed in a timely manner. After identifying these pertinent evaluation criteria, we proceed to assess different types of altruistic contributions.

4.2. Categorization of clusters

Table 1 lists multiple clusters of altruistic activities under the evaluation criterion *social needs*. In order to arrive at a logical catego-

Table 1
Clustering the altruistic acts under the social needs criterion.

Altruistic acts cluster type	Clustering the altruistic acts under the social needs criterion					
Modest acts cluster 1 (S1)	1. Compliment people	2. Acts of courtesy and agreeableness (e.g. open door)	3. Gratitude thankfulness & honoring	4.Surprise people w/ generosity		
Modest acts cluster 2 (S2)	4. Surprise people w/ generosity	5. Keep company and comfort people	6. Help in library	7. Allow children to shadow your job		
Modest acts cluster 3 (S3)	7. Allow children to shadow and learn about your job	8. Offer help to unpleasant tasks at work	9. Work at food bank	10. Cleaning and caring environment	11. Teaching, educating community	
Intermediate acts cluster 1 (M1)	11. Volunteer at homeless shelter	12. Teaching, educating community	13. Community blood drive	14. Organize community service	15. Hospital care program for children's ward	16. Long-term help nursing home
Intermediate acts cluster 2 (M2)	16. Long-term help nursing home	17. Social work and giving advice	18. Donate moderate amount of money (e.g. United Way, Red Cross)	19. Community fund raising event	20. Adopt disabled children	
Intermediate acts cluster 3 (M3)	20. Adopt disabled children	21. Habitat for humanity	22. Moderate micro lending	23. Run for political office		
Big acts cluster 1 (L1)	23. Run for political office	24. Military, police, or fire service	25. Peace corp.	26. Breakthrough invention (sacrifice)		
Big acts cluster 2 (L2)	26. Breakthrough invention (sacrifice)	27. Large micro lending	28. Life time humanity devotion (Mother Teresa)			
Big acts cluster 3 (L3)	28. Life time humanity devotion (Mother Teresa)	29. Sizable (tens of $Billion) money donation	30. Individual sacrifice life to save others			
Big acts cluster 3 (L4)	30. Individual sacrifice life to save others	31. International conflict mediation	32. Humanity relief rescue (e.g. Medical)	33. Global disease cure		



S1	1.Compliment People	2.Acts of Courtesy & Agreeableness (open door)	3.Gratitude Thankfulness, & Honoring	4.Surprising People with Covert & Hidden Generosity
Global Priority	0.06	0.10	0.30	0.55
Global Ideal	1.00	1.70	5.07	9.39

S2	4.Surprising People with Covert & Hidden Generosity	5.Keep Company & Comfort People	6.Volunteer in library	7.Allow children to shadow & learn about your job
Local Priority	0.08	0.14	0.26	0.52
Local Ideal	1.000	1.732	3.206	6.412
Global Priority	0.55	0.948	1.755	3.510
Global Ideal	9.39	16.266	30.115	60

S3	7.Allow children to shadow & learn about your job	8.Offer help to unpleasant tasks at work	9.Work at Food Bank	10.Cleaning & Caring Environment	11.Volunteer at Homeless Shelter
Local Priority	0.047	0.086	0.159	0.240	0.467
Local Ideal	1.000	1.818	3.369	5.074	9.883
Global Priority	3.510	6.381	11.823	17.808	34.687
Global Ideal	60	110	203	306	595

Fig. 4. The AHP model to prioritize the benevolent acts under the social needs.

rization of alternatives under each criterion, the team members with their diverse backgrounds took on the role of critical evaluators and explored each alternative's contribution to achieve the overall goal under the particular criterion. The group was introduced to the nominal group technique (NGT), under which individuals work alone but in a group setting (Delbecq et al., 1975). There are four steps involved: (1) *generating ideas*: each participant silently writes down his judgments for 5–10 min. (2) *Recording ideas: the* coordinator collects the judgment by letting participants share them round-robin fashion (one response per person each time). (3) *Discussing ideas:* The leader asks if there are questions, interpretations, or explanations. (4) *Voting on ideas:* Assuming that the alternatives are homogeneous, each participant privately rates each alternative from no importance "0" to top priority "9". The cumulative ratings are computed and announced. Next, these approximate values were arranged in an ascending order. Members of the committee then worked through a similar procedure again to determine where the pivot alternative from one cluster to the next one should be. That is, the committee determined an initial cluster categorization so that pairwise comparisons within each cluster can be carried out. After the pairwise comparisons, if the priority derived for an alternative exceeds the priorities of the other alternatives by more than an order of magnitude, the larger-priority alternative is moved to a cluster that follows the given cluster (proceeding from small to large) and conversely if the alternative is more than an order of magnitude smaller. The process is continued with care using calculations along with discussion.

Basically, users need to assume a tentative order first and perform pairwise comparisons in small group of elements. Note that there is no definite way to be sure about the order of the alternatives at the very beginning. So the committee needed to work using careful observation and experiment iteratively; bringing about refinements, until in the end they came up with a consistent and agreeable order.

4.3. Altruistic alternatives

In ascending order of these alternatives' importance to the chosen criterion of social needs, we divide them into three levels that contain 10 clusters. They are: (1) Level 1 – Modest acts, e.g. kind gestures and small help; (2) Level 2 – Intermediate acts, e.g. sacrificing career, considerable time, and material wealth; and, (3) Level 3 – Big acts, e.g. devoting significant portions of one's life or money, and taking greater risks to serve. We divide small acts into three clusters, medium acts into three clusters, and large acts into four clusters. We label them as S1–S3, M1–M3, and L1–L4, respectively and list them on the leftmost column in Table 1.

4.3.1. Level 1 – Modest acts

Modest acts are performed to enliven others and make people happy. The small kind acts given in cluster S1 are *complimenting people, acts of courtesy and agreeableness, gratitude,* etc. Modest acts encourage the positive, caring side of human nature. *Gratitude, thankfulness and honoring* acknowledge other's value, while *surprising people with covert and hidden generosity* is love given with thoughtfulness. The modest acts in cluster S2 include *keeping company and comforting people* for physical and emotional connection, *helping in library* and *allowing youngsters to shadow work*. One can

M1	11.Volunteer at Homeless Shelter	12.Teaching, Educating Community	13.Community Blood Drive	14.Organize Community Service	15.Hospital Care Program for Children's Ward	16.Long-term Help Nursing Home
Local Priority	0.02	0.03	0.06	0.10	0.14	0.21
Local Ideal	1.000	1.890	3.249	6.080	8.446	12.391
Global Priority	34.687	66	113	211	293	430
Global Ideal	595	1,125	1,934	3,619	5,028	7,376

M2	16.Long-term Help Nursing Home	17.Social Work & Giving Advice	18.Donate Moderate Amount Money (e.g. United Way, Red Cross)	19.Community Fund Raising Event	20.Adopt Disabled Children
Local Priority	0.03	0.07	0.11	0.16	0.28
Local Ideal	1.000	2.501	4.030	6.252	10.695
Global Priority	430	1,075	1,732	2,687	4,597
Global Ideal	7,376	18,446	29,728	46,115	78,890

M3	20.Adopt Disabled Children	21.Habitat for Humanity	22.Moderate Micro Lending	23.Run for Political Office
Local Priority	0.057	0.122	0.263	0.558
Local Ideal	1.000	2.142	4.629	9.807
Global Priority	4,597	9,848	21,280	45,080
Global Ideal	78,890	169,003	365,185	773,639

Fig. 4 (*continued*)

find that activity #4 (i.e. *surprising people with generosity*) is repeated and shown in Cluster 2 again, due to the need to use it to link the two clusters: S1 and S2. Similar repetition can be found in activities 7, 11, 16, etc.

Helping the needy and the poor at a *food bank and homeless shelter* (see S3) shows the caring and willingness to serve. Compassion can also be extended to include animals and nature. Environmental disasters, green house effects, and climate change make *cleaning and caring for the environment* important. *Teaching and educating community* opens the door for people to learn and appreciate the world's beauty and complexity.

4.3.2. Level 2 – Intermediate acts

Some of the activities in this level include *organizing community service* to bring people together (act #14). *Providing social work and giving advice* (#17), *donating moderate amounts of money* (act #18), *and* occasional *fund raising* (#19) provide opportunities to change society on a larger scale. Giving USA (2009) reports that donation to charitable causes in the US reached $307.65 billion in 2008. As recession continues, the amount declines. In M3, *moderate micro lending* (#22) provides small loans to poor people who have no collateral and do not qualify for conventional bank loans. Beyond money, one may choose to give time to serve the *public office* (#23).

4.3.3. Level 3 – Big acts

Innovation and creativity are essential for a better and brighter future. *Breakthrough inventions* are important in driving technological and social progress. The *Peace Corp* promotes world peace and friendship. Besides the Peace Corp, one may sacrifice for values and beliefs to work *in the military, the police and fire departments*, or sacrifice their lives to provide service and ask for nothing in return.

Sizable monetary donations are a way of giving meaning to wealth and allowing others to "live on" through socially conscious munificence. Donors often experience personal rewards by seeing others' well-being enhanced. Society can show appreciation and gratitude for these altruistic contributions. Finally, *curing global disease* contributes to society on a large scale and deserves the highest kind of recognition.

5. Applying the new AHP model

For each subcriterion (e.g. foods, safety, esteem needs) as listed in Fig. 3, we need to identify appropriate group clusters similar to those listed in Table 1. For the sake of simplicity and clarity, we only illustrate the proposed AHP model methodology using the four main criteria in the paper. Detailed hierarchies for the whole model using all of the 12 subcriteria are available online as supplements titled "Complete Model with 12-Subcriteria".

In Fig. 4 we display the ten clusters of alternatives under the *Social Needs* criterion. Table 2 gives the pairwise comparison matrices with the local priorities of the alternatives shown in the rightmost column of each matrix, which can also be found in the 1st row of each cluster in Fig. 4.

In Fig. 4 we show that we can use the results from pairwise comparisons, and divide them by the weight of the pivot in that cluster, and, finally, multiply them by the pivot's weight from the

L1	23.Run for Political Office	24.Military, Police, or Fire Service	25.Peace Corp	26.Breakthrough Invention (sacrifice)
Local Priority	0.096	0.161	0.277	0.466
Local Ideal	1.000	1.678	2.888	4.854
Global Priority	45,080	75,660	130,182	218,811
Global Ideal	773,639	1,298,430	2,234,102	3,755,093

L2	26.Breakthrough Invention (sacrifice)	27.Large Micro Lending	28.Life Time Humanity Volunteering (Mother Teresa)
Local Priority	0.108	0.226	0.494
Local Ideal	1.000	2.088	4.560
Global Priority	218,811	456,859	997,876
Global Ideal	3,755,093	7,840,304	17,124,874

L3	28.Life Time Humanity Volunteering (Mother Teresa)	29.Sizable (tens of $Billion) Money Donation	30.Individual Sacrifice life to save others
Local Priority	0.094	0.182	0.505
Local Ideal	1.000	1.947	5.396
Global Priority	997,876	1,943,058	5,384,577
Global Ideal	17,124,874	33,345,464	92,406,497

L4	30.Individual Sacrifice life to save others	31.International Conflict Mediation	32.Humanity Relief Rescue (eg. Medical)	33.Global Disease Cure
Local Priority	0.048	0.097	0.238	0.617
Local Ideal	1.000	2.012	4.928	12.769
Global Priority	5,384,577	10,832,968	26,533,253	68,755,097
Global Ideal	92,406,497	185,908,141	455,345,908	1,179,928,909

Fig. 4 (*continued*)

previous less important group to connect the different levels of importance. Eventually, the smallest acts, such as *compliment people,* end up indirectly compared with the biggest acts, such as *curing global disease*.

5.1. Pairwise comparison

The comparisons in Table 2 are made by first comparing *compliment people* with all the modest acts in the same cluster S1, such as *acts of courtesy and agreeableness, gratitude thankfulness and honoring,* etc. The act of *surprising people with covert and hidden generosity* is used again as the pivot in cluster S2, which includes *keeping company and comforting people, helping in library*, etc. Copy all ratings derived in Table 2 to Fig. 4 as local priorities (note however that in S1 the rating is shown as global priority since it's the base for all transformations). Next, we divide all the local priorities in cluster S2 by the local priority of *surprising people with covert & hidden generosity* (0.08), and multiply all the resulting local idealized priorities (1, 1.732, 3.206, 6.412) in this cluster by the global priority in cluster S1 of *surprising people with covert and hidden generosity* (0.55) to arrive at the global priority. In the same manner, the priorities of the intermediate acts in M1, M2 and M3 are derived.

Similarly, we include the M3 act of *running for political office* in the big acts cluster L1. We pairwise compare and synthesize the matrix in Table 2 to find the local priorities (.096, .161, .277, .466) for all cluster L1 acts. Next, in Fig. 4, cluster L1 we derive the local ideals by dividing every local priority by the smallest local priority, 0.096. Multiplying the local ideals (1, 1.678, 2.888, 4.854) by the global priority of *running for political office* (45,080) in the intermediate acts Level M3, we obtain the global priorities for all cluster L1 acts. Similarly, we obtain the global priorities of the cluster L4 acts as 5,384,577; 10,832,968; 26,533,253, and 68,755,097. In the end, we normalize all acts in S1 by dividing each act by the global priority of the smallest act, 0.06 (*acts of complimenting people* in S1). Link them group by group. Eventually, global ideals are obtained for modest acts S1 = (1.00, 1.7, 5.07, 9.39), S2 = (9.39, 16.266, 30.115, 60); and S3 = (60, 110, 203, 306, 595). For intermediate acts M1 = (595, 1125, 1934, 3619, 5028, 7376), M2 = (7376; 18,446; 29,728; 46,115; 78,890), and M3 = (78,890; 169,003; 365,185; 773,639). For big acts L1 = (773,639; 1,298,430; 2,234,102; 3,755,093), L2 = (3,755,093; 7,840,304; 17,124,874), L3 = (17,124,874; 33,345,464; 92,406,497), and L4 = (92,406,497; 185,908,141; 455,345,908; 1,179,928,909). For the other three criteria listed in Fig. 3, we have built the similar sub-structures with different cluster membership, depending on their similarity in contributing to the goal of the criterion.

By multiplying the global ideal priorities with the corresponding criterion weights and summing over the criteria, we are able to determine the overall final scores for each of the 33 activities. For example, the *global disease cure is* of 1,140,230,056 (1,183,020,799 × .398 + 1,179,928,909 × .206 + 1,115,698,094 × .285 + 976,112,301 × .111). In this way, we have created a comparison between the smallest act *compliment people* and the biggest act of *global disease cure;* correspondingly extending the scale beyond 9 to 1,140,230,056. Fig. 5 gives the final score of each act, e.g. the final synthesized value of *global disease cure* is at

Table 2
The pairwise comparisons and local priorities of the altruistic acts under *social needs* criterion.

Social needs (S1)	1. Compliment people	2. Acts of courtesy & aggreableness (open door)	3. Gratitude, thankfulness, & honoring	4. Surprising people w/ generosity	Rating		
1. Compliment people	1	½	1/6	1/7	0.058		
2. Acts of courtesy & aggreableness (open door)	2	1	1/4	1/5	0.099		
3. Gratitude, thankfulness, & honoring	6	4	1	1/3	0.295		
4. Surprising people w/generosity	7	5	3	1	0.547		
Social needs (S2)	4. Surprising people w/ generosity	5. Keep company & comfort people	6. Volunteer in library	7. Allow children to shadow & learn about your job	Rating		
4. Surprising people	1	½	1/3	1/6	0.081		
5. Keep company & comfort people	2	1	1/2	1/4	0.140		
6. Volunteer in library	3	2	1	1/2	0.260		
7. Allow children to shadow & learn about your job	6	4	2	1	0.519		
Social needs (S3)	7. Allow children to shadow & learn about your job	8. Offer help to unpleasant tasks at work	9. Work at food bank	10. Cleaning and Caring environment	11. Volunteer at homeless shelter	Rating	
7. Allow children to shadow & learn about your job	1	1/3	1/4	1/5	1/6	0.047	
8. Offer help to unpleasant tasks at work	3	1	1/3	1/4	1/5	0.086	
9. Work at food bank	4	3	1	1/2	1/4	0.159	
10. Cleaning and Caring environment	5	4	2	1	1/3	0.240	
11. Volunteer at homeless shelter	6	5	4	3	1	0.467	
Social needs (M1)	11. Volunteer at homeless shelter	12. Teaching, educating community	13. Community blood drive	14. Organize community service	15. Hospital care program for children's ward	16. Long-term help nursing home	Rating
11. Volunteer at homeless shelter	1	1/2	1/3	1/7	1/8	1/9	0.017
12. Teaching, educating community	2	1	1/2	1/3	1/4	1/7	0.032
13. Community blood drive	3	2	1	1/2	1/3	1/4	0.056
14. Organize community service	7	3	2	1	1/2	1/3	0.104
15. Hospital care program for children's ward	8	4	3	2	1	1/2	0.144
16. Long-term help nursing home	9	7	4	3	2	1	0.212
Social needs (M2)	16. Long-term help nursing home	17. Social work & giving advice	18. Donate moderate amount money (e.g., United Way, Red Cross)	19. Community fund raising event	20. Adopt disabled children	Rating	
16. Long-term help nursing home	1	1/3	1/4	1/5	1/7	0.026	
17. Social work & giving advice	3	1	1/2	1/3	1/5	0.066	
18. Donate moderate amount money (e.g., United Way, Red Cross)	4	2	1	1/2	1/4	0.106	
19. Community fund raising event	5	3	2	1	1/2	0.165	
20. Adopt disabled children	7	5	4	2	1	0.282	
Social needs (M3)	20. Adopt disabled children	21. Habitat for humanity	22. Moderate micro lending	23. Run for political office	Rating		
20. Adopt disabled children	1	1/3	1/5	1/7	0.057		
21. Habitat for humanity	3	1	1/3	1/5	0.122		
22. Moderate micro lending	5	J	1	1/3	0.263		
23. Run for political office	7	5	3	1	0.558		
Social needs (LI)	23. Run for political office	24. Military or police or fire service	25. Peace corp.	26. Breakthrough invention (sacrifice)	Rating		
23. Run for political office	1	½	1/3	1/4	0.096		

24. Military or police or fire service	2	1	1/2	1/3	0.161
25. Peace corp.	3	2	1	1/2	0.277
26. Breakthrough invention (sacrifice)	4	3	2	1	0.466

Social needs (L2)	26. Breakthrough invention (sacrifice)	27. Large micro lending	28. Life time humanity volunteering (Mother Teresa)	Rating
26. Breakthrough invention (sacrifice)	1	1/2	1/5	0.108
27. Large micro lending	2	1	1/2	0.226
28. Life time humanity volunteering (Mother Teresa)	5	2	1	0.494

Social needs (L3)	28. Life time humanity volunteering (Mother Teresa)	29. Sizable (tens of $billion) money donation	30. Individual sacrifice life to save others	Rating
28. Life time humanity volunteering (Mother Teresa)	1	1/2	1/5	0.094
29. Sizable (tens of $billion) money donation	2	1	1/3	0.182
30. Individual sacrifice life to save others	5	3	1	0.505

Social needs (L4)	30. Individual sacrifice life to save others	31. International conflict mediation	32. Humanity relief rescue (e.g. medical)	33. Global disease cure	Rating
30. Individual sacrifice life to save others	1	1/3	1/5	1/9	0.048
31. International conflict	3	1	1/4	1/7	0.097
32. Humanity relief	5	4	1	1/4	0.238
33. Global disease cure	9	7	4	1	0.617

1,140,230,056 times more important relative to *compliment people* in terms of satisfying human needs.

The grouping or clustering approach adopted here is critical. In most decision problems, there may be two or three groups that differ by orders of magnitude from one another. The AHP scale does not limit us in comparing alternatives if we cluster similar objects into groups and use for a pivot the largest element in one group as the smallest element in the next group. The priorities in two adjacent groups should be sufficiently different, each being one order of magnitude smaller than the other. As a result, the ratings of the smaller set have some impact on the judgment of the larger set. Using this method, comparing a modest act with a highly respectable and noble act becomes possible. Note that the clusters of alternatives under each criterion differ since they depend on where an alternative stands respect to that criterion. This rearrangement of the alternatives has to be done several times, once for each of the criteria.

5.2. Results: the value of benevolent acts

Although humaneness, international disaster relief, and community help are familiar concepts, there has been no openly accepted standard for appraising the value of these benevolent acts. Without an objective means to determine the monetary equivalence of intangibles, society cannot appreciate their true worth. By the proposed AHP model, we uncover a better approach to assign values to altruistic deeds taking place all over the world. Through our method, acts of charity can be valued for the psychological satisfaction they bring to the individuals performing the acts and they can also be assigned significance based on their level of social contribution.

In this paper, we show how benevolent acts can be converted into explicit value. At its extreme, we may equate dollars to priorities, or some similar variant, and then assign a relative fair market price to an act. For example, acts of a lifetime commitment to humanity, e.g. that of Mother Teresa, would be worth $40–$50 million dollars or $45,721,297 according to our account (see Fig. 5, act #28). Investing in the cure of global disease, such as the development of a vaccine for H1N1 flu or AIDS would be worth $1,140,230,056 as suggested by the global weighted score derived in our model (act #33 in Fig. 5). This value is a composite of the values derived under each criterion in which this alternative falls in a higher range of values. We must admit that this is only an illustrative example that may not be perfect, and needs judgment from many more experts in this domain of knowledge and experience (Saaty and Peniwati, 2007). When using greater effort to do the same evaluation in terms of the sub-criteria listed in the 3rd level of Fig. 3, we have obtained a comparable representation of this very large value with $1,190,691,853.

6. Conclusions

If one were to use a scale to rate alternatives one at a time, one would have to make the values of that scale range from zero to 10^{10} in some cases and it would be extremely difficult to judge accurately where the value assigned to each alternative on that scale should fall. We must often guess as to the likely outcome resulting from our decisions. This is also illustrated by the example of our depressed economy. Comparing the many small actions taken to improve the economy through decisions at the local levels with those taken through decisions at the state or the national level, would be difficult and imprecise.

To deal with intangibles scientifically, we have pairwise compared them to derive the relative priorities. Making comparisons is our biological heritage. It was there long before measurement

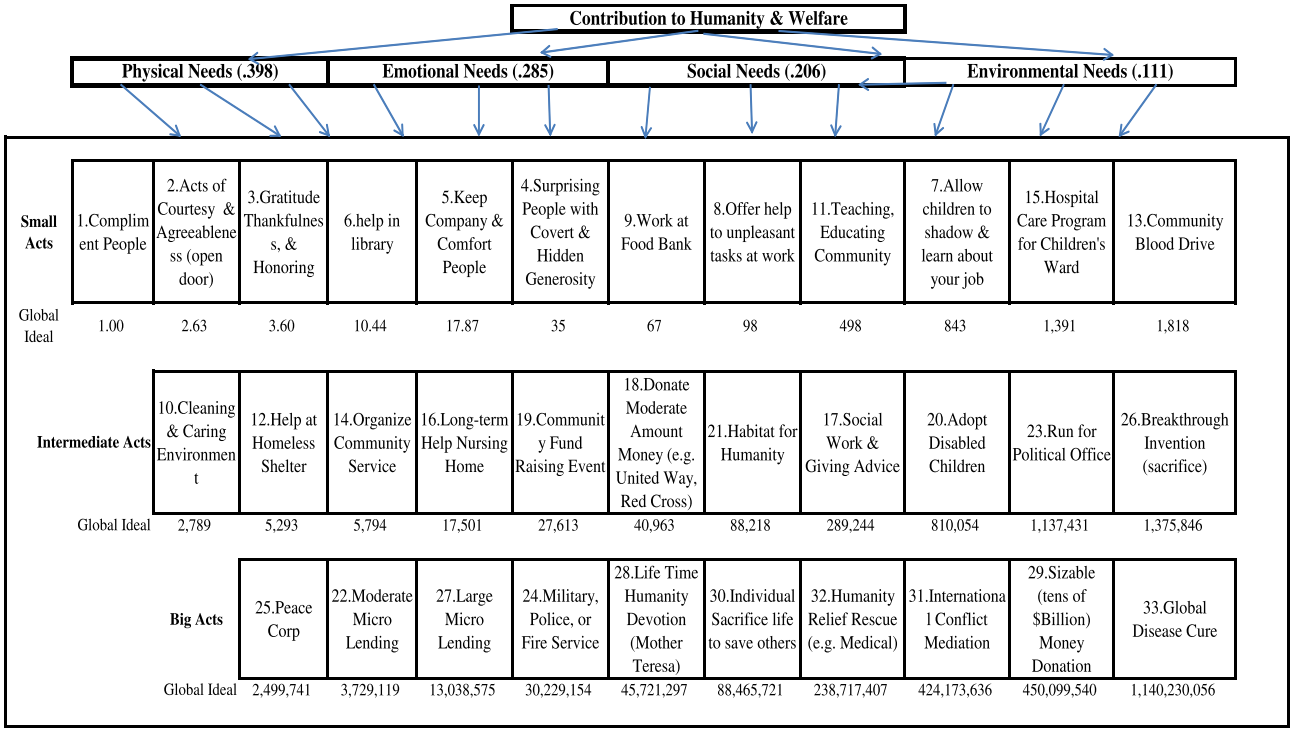


Fig. 5. The final priorities of all studied benevolent acts.

scales were invented with their arbitrary units and gradually used in science to develop scientific theories about the physical universe. But our internal universe of values has been largely ignored. We need to identify the factors that play a significant role in shaping this internal universe to better identify their significance and determine the role it plays that leads us to the future.

The application of the proposed AHP model may be extended to allocate the US budget to federal programs, since the importance of all federal programs are significantly different. Our model could be useful for legislative acts that authorize the expenditure of a designated amount of federal funds for various programs of specific purpose. Please refer to Saaty and Peniwati (2007) for elaboration. In terms of business and education, the proposed AHP model could be applied to the evaluation of schools, supermarkets, and fast food chain stores, whose performance involves tangible and intangible criteria. For example, McDonald's (Wal-Mart) has a string of 32,000 restaurants (7928 Wal-Mart stores) over different regions and countries in the world. By applying the proposed AHP model, corporate executives will have more a comprehensive view regarding the operations and effectiveness of all stores across the board.

In the past four decades, multi-criteria decision modeling has attracted much attention. However, a distinctive area, dealing specifically with the presence of significantly heterogeneous data, has not been explored. The main contribution of this research is the enhancement of the AHP methodology where we illustrate an extensive system with heterogeneous elements. So far as the judgments used are concerned, it is not the measurement precision for a particular alternative that determines the validity of the evaluation results, but the importance we attach to the various criteria used to weight and synthesize those measurement that has greater impact on the outcome. Members of society need to participate in assigning importance to these factors in order to obtain the diversity of information needed to best differentiate among all acts.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2011.05.019.

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