THE AHP, A MULTICRITERIA DECISION MAKING METHODOLOGY FOR SHIFTWORK PRIORITIZATION

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1. Introduction

The Objective of this presentation, is to show a very powerful methodology for decision making process, specifically in the Shiftwork area, where the huge numbers of variables and knowledge to be structured, integrated and synthesized, forces the need for a system analysis process, able to deal with such complexity.

The work flexibility is a very important issue in Chile as in the world too. One of the main problems of work flexibility process is related with the shiftwork systems and its economics, health, social, familiar and environmental consequences.

In the aim of carrying a scientific analysis on this matter, and due to the huge quantity of information, variables and specialists needed, is a pre-requisite to consider that the problem must be analyzed in a multidisciplinary form, with a methodology with the capabilities of measure the effects, integration of views, and able to give a path for the possible conflicts of interest that may rise. All supported in an easy, reliable and mathematical well-defined methodology. To carry this on, was selected the Analytic Hierarchy Process (AHP), one of the most extended and powerful multicriteria decision making method (MCDM). (Saaty, T.L., 1980; Saaty, T.L., 1982; Saaty, T.L., 1992; Saaty, T.L., 1990; Saaty, T.L., 1989).

By the other hand, (adding one more level of complexity to the problem), we have to note that in Chile exist work systems of recent design, in order to respond at the new technologies that allow the exploration and develop of copper mine with an inferior mineral law. This has driving to exploit mines situated over the 3,000m of altitude (4,000m and even 6,000m), with his consequent transport of many workers that live at sea level to places that have different atmospheric pressure and less oxygen concentration. As a result of this, to the original complex problem of design urban shiftworks, we have to add new variables like family isolation, hypoxia exposition and higher risk of accidents.

In order to make better decisions, equalizing the different factors, we first have to dimension the factors in order to synthesize all the variables in play. Until now, we had not such reliable method in ergonomic and physiology as disciplines. (Faundez, M. 2000, Sandoval M. 2000).

This kind of work affects over 40.000 people in Chile, which every day have to expose themselves to high altitude (we even have mines in the north of Chile located at 5960m of altitude).

This workers not only are faced to his own diminish of health but, they also have to face problems related with psychological and family stress (Sandoval, M. 2000; Faúndez, M. 2000, Sandoval M. 2003). The companies, for their shift design, visualize only a part of the variables or criteria that has to be take in account to correct evaluate the problem, so time to time (much more frequently that a good shift design should have), they have to change the workers and/or the shift too, due to the low tolerance of the workers to this levels of stress and physical charge to his physiology. (Sandoval M, Silva J, Villaroel F, Berrios H and Lara D, 2003).

These changes can have a tremendous impact in the company and the accountability numbers, (it will depend of the numbers of changes and the frequency of them). Also the relationship between workers

and the company, can be seriously affected (sometime damaged in irreversible way). But, even in the case of no change of shift or workers, the question arise, how do you know that you have the best possible productivity (shiftwork) for the company?, which of course, is closely related with the level of health and "happiness" of the workers.

As result of all this analysis we were motivated to build a flexible but powerful tool oriented to the integration of very heterogeneous information, even with data coming from tangible or intangible source.

2. The Method.

General description

One of the most relevant part of the AHP, is related with to give a structure to the problem to be solve through the hierarchy. In this phase, the decision group involved should divide the problem on his fundamental components (Saaty, T.L., 1980).

A normal hierarchy is composed by: one global objective (goal), sub-objective (strategic criteria), more specific sub-criteria (technical criteria) and at the last level you can find the alternatives. Is important to clarify that, in the network version we have cluster of criteria instead of levels and nodes instead of criteria, and of course, we can connect in any way we want the clusters and the nodes the model have.

The four steps to build a hierarchy or network structure are (Saaty, T.L., 1986):

1. Identification of the actors (decisores) in order to make a good strategic and technical representation of the problem and its development.

2. Identification of the kind of problem we are deal with: Is the situation that we want to solve the selection of one and only one alternative, or we would like to prioritize all the alternatives and make a ranking of them. Such alternatives will be pairs compares among them with respect a set of criteria or nodes, measuring the behavior of pro and cons for each criterion / node (Saaty, T.L., 1976). This measure can be made in relative (direct comparison) or absolute (existing or created standards of measure) mode. Is also very useful try to identify the four different scenarios of benefits, costs, risks, and opportunities giving by a deep analysis of the alternatives.

3. Clear definition of the Goal. A goal is a path to improve a present situation. The goal is a stand alone level in the hierarchy / network and all the other elements present in the model (alternatives included) are subordinate for the consecution of the goal.

   We have long, middle and short term objectives, and this differentiation will influence directly in the process of building the hierarchy/network.

   The goal and objectives will be defined by the group, this is a crucial part of the modelling process, since here will probably merge the relevant differences from the point of view of the group, those differences instead to flatting (and destroy) the model should help to enrich it, giving to the model all the corners and shapes for the correct representation of reality. In order that all the needs and global interest of the group have been captured.

4. Criteria /(clusters and nodes) identification. The criteria /(cluster and nodes) are the relevant dimensions of the problem in terms of importance and difference that are able to do in the alternatives level /cluster. They should represent the preferences and differences of the group. They can be tangible or intangible it doesn't matter, what really matter is the richness of the information and connectiveness that bring inside, in terms of reaching the defined goal.

5. Identification of the Alternatives. The alternatives, are specific and feasible ways to reach the goal The alternatives (the shifts), will present pro and cons in each criterion, and this identification should help in a better definition for all the steps before.

3. Specific description application (The Work)

To get the work done, we gathered 23 different specialist;, 3 physiologist, 2 internal doctors (1 helping the facilitator process), 2 anthropologies, 2 psychologists, 2 ergonomics, 1 lawyer, 2 mathematical engineers, 2 modeling engineer (facilitators), 1 business engineer, 1 biochemistry, 3 ergonomics engineers, 2 engineers in risk prevention. All of them with at least 5 years of experience in research or applying the know-how in their own area, specially into shiftwork systems related with the mining field.

As a first step, all of them were prepared in the basic concepts of Analytic Hierarchy Process (AHP). Once prepared, were formed round tables to discuss the problem (with the help of the facilitators and the software Expert Choice 2000 armed with the Team work option and keypads for voting.
This round tables, were conducted by 1, 2 and sometime 3 experimented facilitators to get trough the building model process and the integration of the different views into the model. The model was build and analyzed under different situations, once the model (or part of it) seemed to be reasonable, the importance of the criteria were calculated, and again the specialists had to revise if the resulting priorities represented their own knowledge and experience on that specific issue. This process was repeated for each part of the model where the specialist or group of specialists had to give their opinion about one specific issue.

At the end, the model was build in an holistic participative way for the strategic and high criteria (the upper levels of the hierarchy), but with a specific *"reduced"* way for the terminal and low criteria (the lower levels of the hierarchy).

The next figure (Figure 1), show an example of the shiftworks hierarchy model, the Goal: Shiftwork Prioritation (in term of risk or health impact) presented in blue, the 3 main or strategic criteria that govern all the model decision process: The Workers aspects, the Enterprise aspects, and the Community Aspects, presented in yellow, and some of the 450 subcriteria: physical capacity, psychosocial variables, effects over the organization, economic value impact, regional development, citizen participation, family and social risks, that are present in the whole model The Shiftwork Asset. This shiftwork Asset, represent a one of the four general or global models, that have to be customized when used to evaluate or design a specific shiftwork to the costumer (enterprise CEOs, workers, community).
The four models were build to take in account the different environmental issues that derive from the geographic location where the work is done, (this is something like the border conditions of the problem).

The Four Shiftowrk Asset Models are:
1.-Work in High Altitude with a Camp (near to the work)
2.- Work in high altitude without a Camp (near to the work)
3.- Work in Sea Level with a Camp (near to the work)
4.- Work in Sea Level without a Camp (near to the work)

Note: Here high altitude is defined as: "over 3,000m", and camp near work as: "living in a existing camp (close to the work place), without his family.

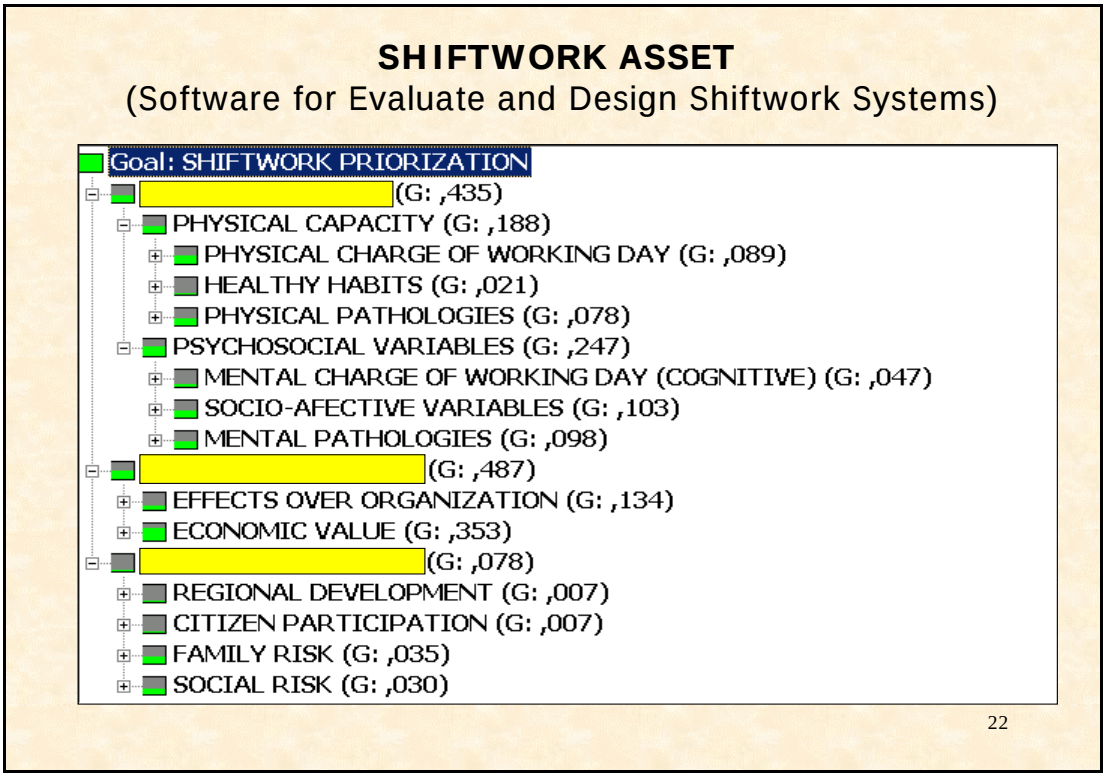

Figure 1 The Shiftwork Asset: a general software to evaluate and design shiftwork systems

Once the modeling part is ended, begin the criteria weighting process, this process is performed by filling matrices of pair comparisons of the criteria in each level of the hierarchy, using the gathered upper criterion as the element of comparison for the hanging criteria. The comparison are disposed in a square, reciprocal, and diagonal unitary matrix (Saaty, T.L. 1976a). Then is obtained the greater eigenvector which represent the stable equilibrium point of the decision matrix, (graphically, this vector represent the condensed form to asses all the path to bring information from any point X to any other point Y in a connected graph). So, this vector represent the measure of the priorities of all participants (individually and as a group decision). Of course, this vector have all the arithmetic attributes of a proportional measure scale (metric).

At the same time, this way of asses give an important scalar value, know as the greater eigenvalue of the matrix, this eigenvalue is related with the level of consistence of the answers captured in the pair comparison matrix. For the specialists, the level of consistence required was high, since this are the people that represent the technical knowledge of the problem, and is expected they may handle almost perfect his own piece of information (knowledge). In the case of the actors or participants related with the strategic criteria (holistic view), the level of consistence required was little lower. (The relaxation of this condition, was always asking for the minimum consistence required by the method itself, which depend of the dimension of the comparison matrix).

Doing so, we have build the decision metric (with his consistency), for each actor, as for the all decision group. This metric, represent the way of prioritizing (somehow his way of thinking), for each person as well as for the complete group of decisores. With this way of work, we even can evaluate (measure) the differences of each point of view (the “distance” of the system values of any actor to any other or to the group), catch who are the variables responsible for the mains differences, why are produced and asses his exactly value for better agreement or conflict resolutions. We have to remember that in this kind of problems we will face some important conflicts between unions and managers and/or CEOs, even sometime (when exist and have some decision power), with the surrounding community itself.

4. Results.

One of the most important results of this work is the “Shiftwork Asset Software”, a general system in software format (Figure 1), made it to asses almost any kind of shiftwork and also able to generate new shifts under a cooperative way of build shifts, between the different actors and views presents in this decision making policy (manager, workers, family, legal restrictions, etc.), as well as able to carry out threshold analysis (Figure 2) in a comprehensive manner.

The metric that we get, allows us to study different scenarios (Figure 3). Is also important to note that this system (due his metric qualities), has few important capabilities like: cardinal shifts ranking, views integration, conflict resolution facilitation, measurement of the real effect of the Shiftwork over the workers, the enterprise and the community for each criterion, and for all the model, to build objective thresholds, which result in a very powerful tool to minimize the differences, focalizing the negotiation only in the relevant criteria, to build long term pacts (solutions) due to the search of stable points of equilibrium for the solution. We also have to note that all this process is embedded in the mathematics that support the Shiftwork Asset System.

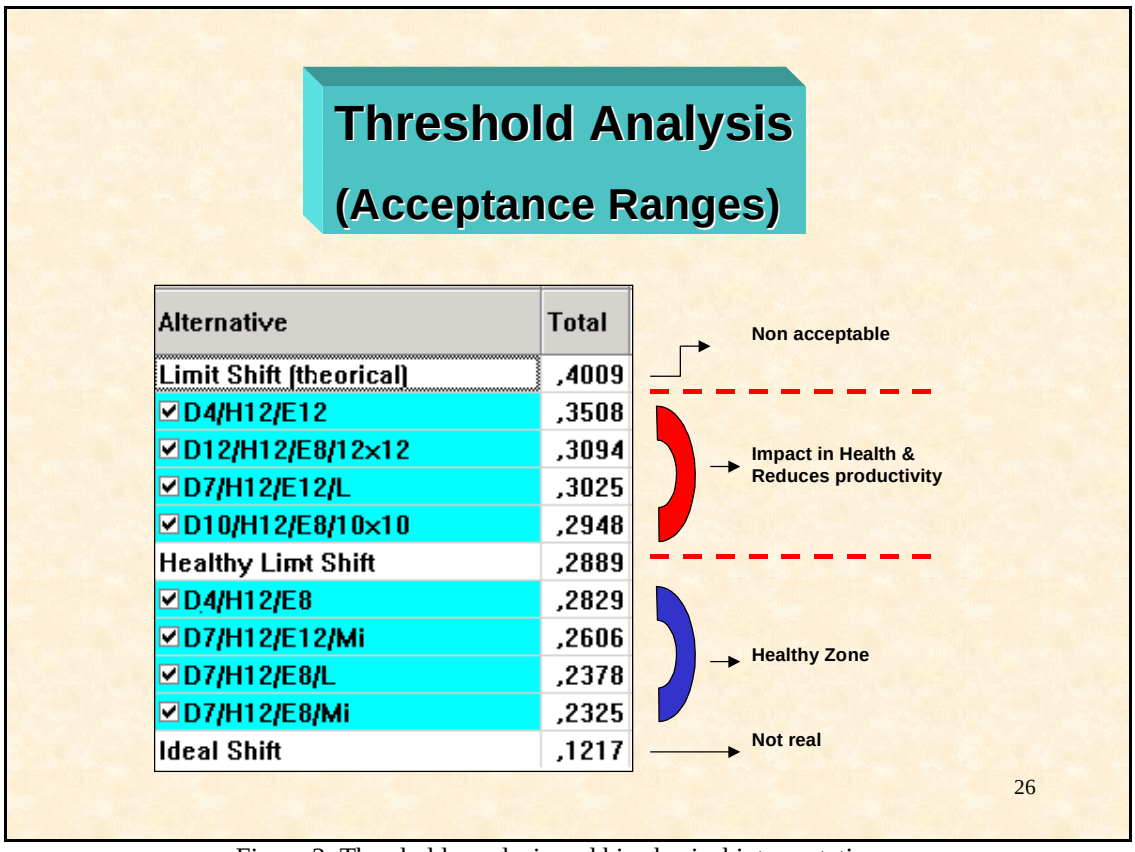

Figure 2: Thresholds analysis and his physical interpretation

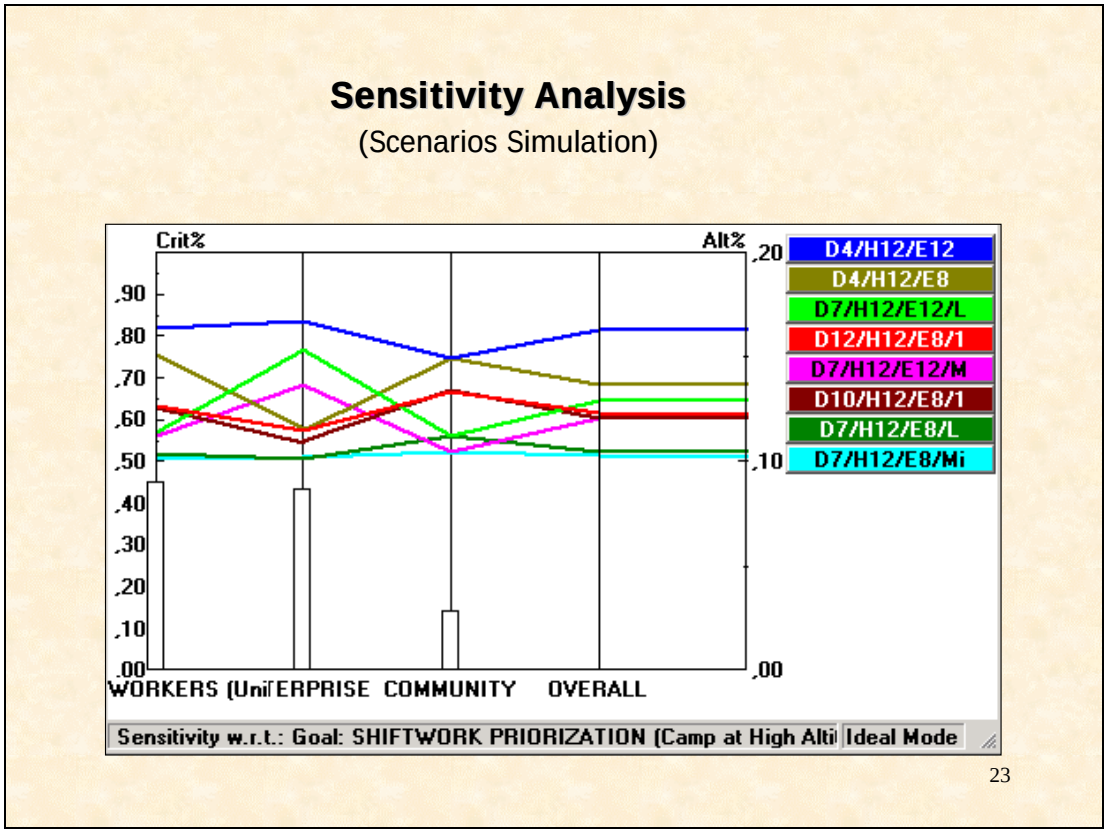

Figure 3: Sensitivity analysis (Scenarios Simulation)

5. Discussion.

The first relevant concept for the Shiftwork Asset, is that this system is a general asset software that has to be customized to the enterprise reality.
This kind of model development to evaluate shiftwork systems, is able to identify the most relevant variables for each decisores group (enterprise and company's workers), therefore it identifies those variables where an intervention to improve the shift system can be more profitable. However, although their structure is applicable to many companies you always have to keep in mind that requires a particularization (tailor-made) for the culture and the reality of the company, this is some kind of customization effort.

The structure of the hierarchical model can be observed in the Figure 1, where the model identified the tree relevant aspects: workers, company and community. As observed in the figure 1 the importance of the workers and the company are very similar, instead the importance of the community aspects is low, this is an specific application result of the Shiftwork Asset in a mine with high altitude and existing camp.

Each variable shows among parenthesis the value of relative importance that represent how the given information has been considered as well as the relationship among the variables. The same thing can be observed in figure 2, in which is shown the ranking gave by the model too. This is an impact assessment model, for the shiftworks and of course the shiftwork system that end with the smallest score it will be the advisable one to be implanted.

The metric generated allows to study different scenarios of behavior for the variables in the different levels of the hierarchy. This is shown in Figure 3 with a graph of sensibility in that we can vary the importance of the variables and look if our decision stays stable with those changes. Doing the same is possible to find the values for the break points for the set of criteria that could change the decision.

The results are expressed in a cardinal ranking from bigger to smaller value. This metric reflect the real differences among a shiftwork alternatives, This stand for how much preferable is one shiftwork over other.

The creation of metric for each variable and inside this, the identification and "metrification" of intensities scales allows to evaluate each alternative in its limit of tolerance. Starting with this concept we can define thresholds of impact that generate a reference frame for the shiftwork system selection (figures 2).

Given that the model contains a great variety of information it allows applying this to other areas of the planning of shiftwork systems and not only to those works in altitude. For example, it can be applied to shiftwork so dissimilar as urban systems of shift of companies of service, or in oil platforms.

Another advantage of the computer system is the facilitation process which allow a truly participation of many company-groups including their observations and/or opinions regarding the variables in play. This process is translated (on line), in the production of a model with the necessary information to make sustainable decisions in a very brief period of time.

In front of the current form of making decisions in this area, in which we find frequently slanting as a decision only based on the economic value or in the production that they fail or they generate conflicts with the unions and with the independent workers that produce big losses to all the parts of economic type, of trust, of development, etc., this form allows to settle down the priorities clearly in transparent way and to arrive to systems with great stability supported about the consideration of all the actors.

Finally the company, in each group or together, it can improve the system incorporating that entire information because this system is open, but with the advantage that the incorporation of new information doesn't means to re-do the entire model, but only to express the relationships of the new variable with the other ones

By the way, at the very last view, what really care to represent the real world and make better decision (in this case to choose the best shift), is first to have all the information available (is irrelevant if is tangible or intangible), build the relations that represent those information (in a structural way) and then weight the importance of the variables to asses the current alternatives (shifts), or design the new ones.

This Methodology have been applied in many different area, we as Fulcrum, have been applied in more than 50 different projects in Chile, with very good results as a predictor system and as a measure system where no measurement is available. (few of those projects can be read it in the list of papers below).

The AHP method is easy to understand and use, mainly because it result very natural to the way we think and structure our own decisions.

If we add the options that the system has to work with group of people (intended as one person one decision metric) and integrate visions to obtain the final answer we met with a real powerful tool.

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