# Resilometrical modeling of interactions in social resilience dimensions

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**Abstract**

The concept of resilience has been the subject of several researches particularly in areas such as ecology, psychology, economics etc. According to the discipline, resilience takes various definitions. Yet, in general, it is clear from those definitions that resilience is the ability of an entity to resist a shock, to face a disturbance, to recover or bounce back after a traumatic event. In recent years, there is increasing concern estimating and analyzing the process of resilience. In this context, resilience is seen as the result of several characteristics or factors known as dimensions of resilience.
In this paper, we present a summary of the main dimensions of resilience using various documents and articles. Then, we present a model for analyzing the interactions between these different dimensions. This model is an adaptation of the structural equations modeling with latent variables in the context of resilience.

***Keywords*** : *Résilience, Dimensions, Structural Équations Modeling with Latent variables, PLS Path Modeling.*

## 1. Introduction

In the literature, there is a variety of definitions of the resilience concept. However, from a conceptual point of view, we can distinguish four main types of definitions. Resilience can be seen as a *capacity*, as a *process*, as a *result* or as a *capacity*, a *process* and a *result*. In our study we adopt the definition of resilience as an *adaptive dynamic process* as supported by Anaut [1], Michael Rutter [2] and by Richardson [3]. For those authors, resilience is seen as the process of adaptation to stressors, adversity, changes and opportunities. In this context, when a social system (individual, family or community) is facing a traumatic event, he loses his balance because of the shock that created a rupture or break. This takes the system to use the protective factors he has to adapt or overcome the trauma. The interactions between risk factors (shocks, adversity) and protective factors may lead to resilience or not. Protective factors are composed of personal factors and environmental factors that interact to allow the system to adapt and bounce back eventually. According to this model, resilience is not static but dynamic and depends on individual capacities. In other words, one can be resilient to a situation and will not be in another situation. The resilience is therefore a construction, an evolutionary process as shown our model of resilience in the following figure:

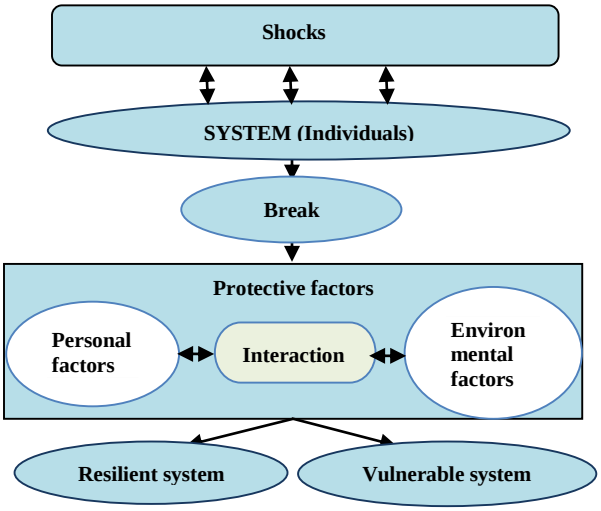


Fig.1 Model of resilience

The model proposes the combination of personal and environmental factors for the analysis of resilience. Furthermore, this model above allows, the analysis of

the resilience of an individual, taking into account the actions at family and community level as well as the influence of the whole society.

## 2. Researches on the dimensions of social resilience

Several research studies highlight a wide variety of characteristics of resilience's dimensions. However, because of the diversity of definitions of the concept of resilience, there is no consensus yet on those dimensions. The dimensions proposed in this article are the result of a synthesis analysis of those proposed by several authors and organizations. Specifically, these dimensions are derived from the works of Boris Cyrulnik [4], Berkes, Colding and Folke [5], Hollnagel and al. [6], Woods [7], Westrum [8], Wolin [9], Manciaux [10], Vanistendael and Lecomte [11], Lyons [12], Clausen [13], Werner [14], Werner and Smith [15], Rutter [2], Jean-Michel Reinert [16], Achiépo Odilon Yapo [17] and Kouadio Odounfa Alice [18]. In addition to those authors, the dimensions taken into account include those used in the measurement tools for developing resilience as the Resilience Scale for Adults (RSA) proposed by Odin Hjemdal, Oddgeir Friborg, Monica Martinussen and H. Rosenvingeen [19], and the Connor Davidson Resilience Scale (CD-RISC) from the work of Kathryn Connor and Jonathan Davidson [20].

The analysis of the different dimensions used in these works can help us observing that most theories are based on individual level for the descriptions of the resilience process. Thus, data are collected on the abilities, skills and resentments of individuals. Only a few studies highlight the need to use data on environmental factors. In addition, most of the work studied the resilience of individuals by analyzing their suffering and the strategies they use to bounce back eventually.

## 3. Main dimensions of social resilience

### 3.1 Main dimensions

A careful analysis of the different dimensions proposed in the literature by authors and works considered, lead to the definition of ten key dimensions for the analysis of social resilience process. These dimensions are the following:

1) The sense of coherence
2) The awareness
3) The sense of humor
4) The feeling of not guilty
5) pro- social attitude
6) The ability to solve problems
7) The collection efficiency
8) The adaptation to environment
9) The feeling of internal control
10) The spirituality

### 3.2 Selection criteria

The ten (10) main social resilience's dimensions mentioned above are the result of a rigorous selection made among the various dimensions proposals contained in the literature and based on the following criteria:

- The dimension frequency in the different works: We retained the dimensions that have been cited by many authors in order to reduce the risk of the subjectivity. Some dimensions are often replaced by synonyms to deal with different proposals together.
- Relevance: it is measured by the degree the proposed dimension is correlate to the concept of resilience, and the credibility of its source of publication.
- The importance of personal and environmental level in the proposal: To better characterize the resilience of a system you must take into account its personal and environmental description. Unlike many works that obscure the environmental aspect of the resilience, the selected dimensions have to integrate these two aspects of the social resilience.

## 4. Description of the main dimensions

### 4.1 The sense of coherence

It is « a dispositional orientation that can help prevent a breakdown and a break under very stressful situation» [21]. This feeling suggests a decline, an objectification and an analysis of the adverse situation. People who have a high sense of coherence may be less easy to be affected in terms of behavior and emotion by the stressors they experience. Moreover, the sense of coherence determines the ability to control the inconsistencies and life events.

### 4.2 The awareness

It is the ability to identify problems, their sources and to find solutions while being attentive to others. The awareness characterizes individuals whom effective action can be taken to have a success. Individuals who have not realized their suffering situation can become resilient in the social context.

### 4.3 The sens of humor

This ability is, according to Freud, the highest of all. It is studied in research on resilience. It is found in the works from B. Cyrillic, Stefan Vanistendael and Jacques Lecomte. Gisele Tessier [22] defines humor as «a state of mind that overcomes adversities and sorrows turning in derision. Thus, too painful affects are let at a distance through smiling; humor is a resource for us to overcome difficulties. »

### 4.4 The feeling of not guilty

Guilt is a feeling that is often characterized by anxiety and / or frequent depression. It is defined as an emotion on an individual or a social group and is based on the feeling, whether justified or not, which carries a personal responsibility in an unfortunate situation. Thus, for many researchers, have a sense of not guilty, greatly contributes to the resilience of the individual.

### 4.5 The pro-social attitude

The pro- social attitudes enable an individual, when the need arises, to have recourses and social support like a guardian. All the authors concerned about the concept of resilience have mentioned relationships with others and the importance for the individual, to have pro-social attitudes as resilience elements. We can quote among others [23]

### 4.6 The ability to solve problems

This feature is the ability to seek solutions to problems, to find resources. It is a pledge of action for individuals. The ability to solve problems is a fundamental characteristic of resilience.

### 4.7 The perception of self-effectiveness

This is one of the fundamental elements of the theory of Bandura [24]. It concerns the beliefs of people in their ability to realize their ambitions. There is nothing to expect from individuals that project a negative image of themselves because the perception of oneself determines our mental resilience.

### 4.8 The adaptability to environments

The life and work place can positively or negatively influence the individual. The ability to adapt to this environment is therefore an important feature allowing the individual to activate resilience regardless of the place in which it is located.

### 4.9 The feeling of internal control

This is a very important feature in the process of resilience in [3], [25]. Indeed, such a feeling encourages the individual to believe that he personally controls in a situation. It allows a person to be active in solving a problem since his conviction can change a situation.

### 4.10 The feeling of internal control

Some social scientists argue that spirituality is a contributing factor to high resilience. It is one of the factors that give meaning to life. It refers to the meaning, the purpose and values of human life. Spiritual beliefs can lead to resilience when social actions are ineffective.

## 5. Modeling of relations among the dimensions of resilience

### 5.1. The GSCA model

The dimensions of resilience maintain among themselves a cause and effect relation. Taken alone, a dimension can itself characterize resilience. It is this complex interaction among them that stimulates and characterizes the social resilience process. However, the resilience dimensions are abstract concepts of high level. It is impossible to observe them directly. They are valued by using indicators that characterize them. From the point of view of Statistics, the resilience dimensions latent variables (unobservable) and indicators that characterize them are called manifest variables (or observable). It is therefore natural to model the relationships among the different dimensions of resilience using statistics techniques of Structural Equation Models of Latent Variables (MESVL). In this article, we use precisely the approach GSCA (Generalized Structural Component Analysis)

The GSCA model separates the endogenous variables and exogenous variables, and applies the concept of endogenous variables on both latent variables and the manifest variables. Thus, the manifest variables of

formative blocks are considered exogenous and those of reflective blocks are considered endogenous. To be clearer, we will use the formalism of the PLS (Partial least Squart) approach knows as PLSPM (PLS Path Modeling) [26], adapting to GSCA. Specifically, it will be by exhibiting vectors and matrices conventionally used in the GSCA ratings from PLSPM formalism.

### 5.2. The model notations

To present the modeling method, we use a set of notations. These differents notations are more complexe than those used in the classical structural equation modeling, especially in classical PLS Path Modeling approach. These notations are :

- ✓ $D$ the number of resilience dimensions taken into account;
- ✓ $T$ the time horizon for measuring resilience;
- ✓ $N$ the number of individuals used in the data collection;
- ✓ $\xi_d^t$ the latent variable of the dimension $d \in [1, D]$ at the time $t \in [1, T]$
- ✓ $X_{dj}^t$ The *j*th manifest variable associated with the latent variable $\xi_d^t$ (block $d$);
- ✓ $n_d^t$ the number of block manifest variables *d* at the time $t$
- ✓ $n$ the total number of manifest variables ( at each time $t$) ;
- ✓ $x_{dj}^t$ the value of the *j*th manifest variable of latent variable $\xi_{dt}$ taken by the *i*th individual;
- ✓ $Z_{end}$ the vector of all the endogenous manifest variables;
- ✓ $Z_{exo}$ the vector of all exogenous manifest variables ;
- ✓ $L_{end}$ the vector of all the endogenous latent variables ;
- ✓ $L_{exo}$ the vector of all exogenous latent variables;
- ✓ $Z = [Z_{end}, Z_{exo}]$ the vector of all the manifest variables ;
- ✓ $\Psi = [Z_{end}, L_{end}]$ the vector of all the endogenous variables (manifest and latent)
- ✓ $\Gamma = [L_{end}, L_{exo}]$ the vector of all latent variables;
- ✓ $E_I$ the error vector on the latent variables in the structural model ;
- ✓ $E_M$ errors adjustment vector of manifest variables in the measurement model ;
- ✓ $E_\delta$ errors adjustment vector of latent variables in the measurement model.

## 6. Dimensionals interactions models matrix form

Based on these ratings, it is possible to provide a matrix writing of structural equation model of latent variables. In fact, when the measurement model includes a set of reflective blocks, we can write:

$$\xi_d^t = \sum_{j=1}^{n_d} \omega_{dj}^t x_{dj}^t + \delta_d^t \qquad (1)$$

$$\Rightarrow \underbrace{\begin{pmatrix} \xi_1^1 \\ \dots \\ \xi_D^1 \\ \dots \\ \xi_1^T \\ \dots \\ \xi_D^T \end{pmatrix}}_{{}^t\Gamma} = \underbrace{\begin{pmatrix} \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & (\omega_{dj}^t) & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \end{pmatrix}}_{{}^tW} \underbrace{\begin{pmatrix} x_{11}^1 \\ \dots \\ x_{1n_1}^1 \\ \dots \\ x_{D1}^T \\ \dots \\ x_{Dn_D}^T \end{pmatrix}}_{{}^tZ} + \underbrace{\begin{pmatrix} \delta_1^1 \\ \vdots \\ \delta_{D_e}^1 \\ \dots \\ \delta_1^T \\ \vdots \\ \delta_{D_e}^T \end{pmatrix}}_{{}^tE_\delta}$$

$$\Rightarrow {}^t\Gamma = {}^tW {}^tZ + {}^tE_\delta = {}^t(ZW + E_\delta)$$
$$\Rightarrow \Gamma = ZW + E_\delta \qquad (2)$$

Similarly, when the measurement model includes a set of formative blocks, the relations between the manifest variables and variables are written:

$$x_{dj}^t = \pi_{dj}^t \xi_d^t + \epsilon_{dj}^t \qquad (3)$$

$$\Rightarrow \underbrace{\begin{pmatrix} x_{11}^{1(end)} \\ \dots \\ x_{1n_1}^{1(end)} \\ \dots \\ x_{I1}^{T(end)} \\ \dots \\ x_{In_I}^{T(end)} \end{pmatrix}}_{{}^tZ_{endo}} = \underbrace{\begin{pmatrix} \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & (\pi_{dj}^t) & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \end{pmatrix}}_{{}^tC} \underbrace{\begin{pmatrix} \xi_1^1 \\ \dots \\ \xi_D^1 \\ \dots \\ \xi_1^T \\ \dots \\ \xi_D^T \end{pmatrix}}_{{}^t\Gamma} + \underbrace{\begin{pmatrix} \epsilon_{11}^1 \\ \vdots \\ \epsilon_{1n_1}^1 \\ \dots \\ \epsilon_{I_1}^T \\ \vdots \\ \epsilon_{In_I}^T \end{pmatrix}}_{{}^tE_M}$$

$$\Rightarrow {}^tZ_{end} = {}^tC {}^t\Gamma + {}^tE_M = {}^t(\Gamma C + E_M)$$
$$\Rightarrow Z_{end} = \Gamma C + E_M \qquad (4)$$

Finally, the relationships described by the structural model, that is to say, the various relationships between the latent variables are written:

$$\xi_d^t = \sum_{\xi_k^t \to \xi_d^t} \beta_{dk}^t \xi_k^t + \sum_{\xi_k^{t-1} \to \xi_d^t} \gamma_{dk}^t \xi_k^{t-1} + \zeta_d^t \qquad (5)$$

$$\Rightarrow \underbrace{\begin{pmatrix} \xi_1^{1(end)} \\ \dots \\ \xi_{D_e}^{1(end)} \\ \dots \\ \xi_1^{T(end)} \\ \dots \\ \xi_{D_e}^{T(end)} \end{pmatrix}}_{{}^tL_{end}} = \underbrace{\begin{pmatrix} \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & (\beta_{dk}^t + \gamma_{dk}^{t+1}) & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \end{pmatrix}}_{{}^tB} \underbrace{\begin{pmatrix} \xi_1^1 \\ \dots \\ \xi_D^1 \\ \dots \\ \xi_1^T \\ \dots \\ \xi_D^T \end{pmatrix}}_{{}^t\Gamma} + \underbrace{\begin{pmatrix} \zeta_1^1 \\ \vdots \\ \zeta_{D_e}^1 \\ \dots \\ \zeta_1^T \\ \vdots \\ \zeta_{D_e}^T \end{pmatrix}}_{{}^tE_L}$$

$$\Rightarrow {}^tL_{end} = {}^tB{}^t\Gamma + {}^tE_L = {}^t(\Gamma B + E_L)$$
$$\Rightarrow L_{end} = \Gamma B + E_L \quad (6)$$

## 7. The basic principle of dimensional interaction models

The structural equation models with latent variables can be summarized simply by the following system of three matrix equations:

$$\begin{cases} \Gamma = ZW + E_\delta \\ Z_{end} = \Gamma C + E_M \\ L_{end} = \Gamma B + E_L \end{cases} \quad (7)$$

If we write down $A = [C, B]$and$E = [E_M, E_L]$, by combining the last two equations, the set of endogenous variables is given by:

$$\Psi = [Z_{end}, L_{end}]$$
$$= [\Gamma C + E_M, \Gamma B + E_L]$$
$$= \Gamma[C, B] + [E_M, E_L]$$
$$\Rightarrow \Psi = \Gamma A + E \quad (8)$$

In GSCA method, errors in the vector are non-existent. This is due to the fact that the algorithm estimation directly calculates the relation$\Gamma = ZW$ . Once the lodings estimated, $Z$ being already known. Therefore, taking into account the first relation which states that

$$\Gamma = ZW + E_\delta = ZW \quad (9)$$

We have:

$$\Psi = \Gamma A + E = ZWA + E$$
$$\Rightarrow E = \Psi - ZWA \quad (10)$$

The method GSCA seeks the MESVL parameters (structural equation model with latent variables), that is to say the elements of matrices $W$ (lodings), $C$ (weight of manifest variables) and (structural coefficient) that minimize the measurement errors. Technically, noting $tr(.)$ the trace operator of a square matrix, the problem is to finding the minimum of the following function:

$$f(W, C, B) = tr[M_f] \quad (11)$$

Where

$$M_f = tr[(E = \Psi - ZWA)^t(E = \Psi - ZWA)] \quad (12)$$

The optimization of such a function is very complex. To do so, the method uses by the algorithm GSCA is the least squares alternated. The GSCA method is thus very useful to study the relationships among the different dimensions of resilience. However, it is important to understand that its use requires prior knowledge about these relationships.

## 8. Conclusion

The establishment of a consensual framework between researchers for a harmonization and validation of social resilience dimensions is needed. Such action also involves harmonization of definitional concepts associated with resilience. This is fortunately part of the initiatives of the International Joint Research Unit on Resilience (UMI Resilience), in which our work fit. This consensus is of the utmost importance since the analysis model relationships among dimensions is just one model among others that the research in Resilometrics [27] try to implement for a better analyzing of resilience process. These activities are part of an extensive project to develop a set of appropriate mathematical and computational tools to the resilience aiming to create the Engineering Resilience.

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