An Enterprise Coherence Quantification Framework for General Enterprise Architecting

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Abstract. Enterprise coherence pertains to the extent to which all relevant aspects of an enterprise are connected in such a way that these connections facilitate an enterprise in obtaining/meeting its desired results. The GEA (General Enterprise Architecting) method treats enterprise coherence as something that can be governed explicitly. GEA's Enterprise Coherence Framework (ECF) is qualitative in nature. Being able to really measure enterprise coherence would greatly support the analysis of enterprise coherence. In this paper we setup a research approach for developing enterprise coherence metrics and perform a first step in working towards an Enterprise Coherence Quantification Framework (ECQF) as part of a methodology. A case from GEA training practice is used for validation of a first application of the ECQF.

Keywords: Enterprise Coherence · Enterprise Coherence Quantification Framework · GEA · Enterprise Architecture · Strategy Framework

1 Introduction

Strategies fail due to a lack of coherence and consistency [9]. Coherence between various enterprise facets is essential for success [10]. Leinwand and Mainardi [14] showed a relation between enterprise coherence and enterprise performance. Complex System Governance (e.g. [13]) teaches that -since system viability relies on design [12] - the viability of an organization is threatened by lack of coherence in design. Own research shows that coherence in organizations is unsatisfactory on average, and even poor when it concerns enterprise design [21]. Measurement of the level of enterprise coherence would greatly support the analysis -and

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thereby- governance of enterprise coherence [21]. This paper explores a quantification framework for strategy planning frameworks, and more specifically GEA, as a step in gradually working from simple to more refined ontologies.

2 Theoretical Background

The notion of enterprise coherence was coined by Wagter [8] as part of the GEA (General Enterprise Architecting) method [8,24]. GEA defines *enterprise coherence* as *"the extent to which all relevant aspects of an enterprise are interconnected, such that these connections facilitate an enterprise in achieving its management's desired results"* [25]. Based on the GEA definition, the GEA method includes the Enterprise Coherence Framework (ECF) [8], that evolves around the notions of *Level of Purpose* and *Level of Design* and involves ten relevant aspects of coherence: Mission, Vision, Core Values, Goals, Strategies, Perspective, Core Concept, Core Model, Guiding Statement, and Relevant Relationship. The ECF with a few example perspectives is shown in Fig. 1. With an ECF in place, it is possible to address business issues with coherent solution elements [8]. The ability to quantify enterprise coherence is expected to aid GEA practitioners and scholars in their analysis [8].

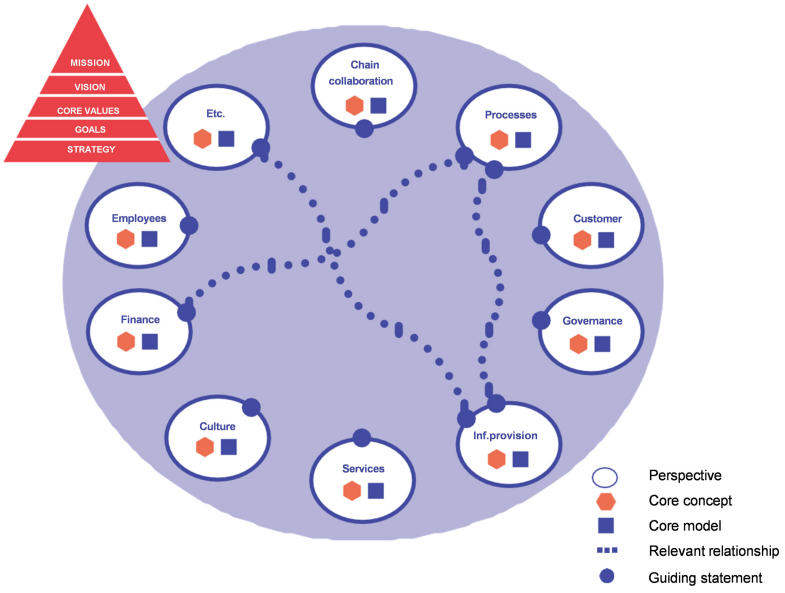

Fig. 1. The Enterprise Coherence Framework (ECF) within GEA

Understanding the interactions between the components of a system is key to understanding it on a quantitative and predictive level [18]. Even when mechanisms are unexplained, graphs and their topology allow to understand its properties [18]. Earlier research [20,22] showed multiple graph-based approaches to

coherence. This makes the ability to express a strategy planning framework as a graph a key requirement.

3 Research Design and Methodology

The research to quantify enterprise coherence falls into the higher level engineering cycle [11] of enterprise coherence governance [6] as part of enterprise architecture (EA), which again facilitates organizational design that is consistent and coherent in supporting the organization's strategy and viability. The relationship between the coherence in the design of an organization and its viability [12] and the demonstrated lack of enterprise coherence governance [21] drives us to the research effort of quantifying enterprise coherence. The research positioning is as follows Fig. 2:

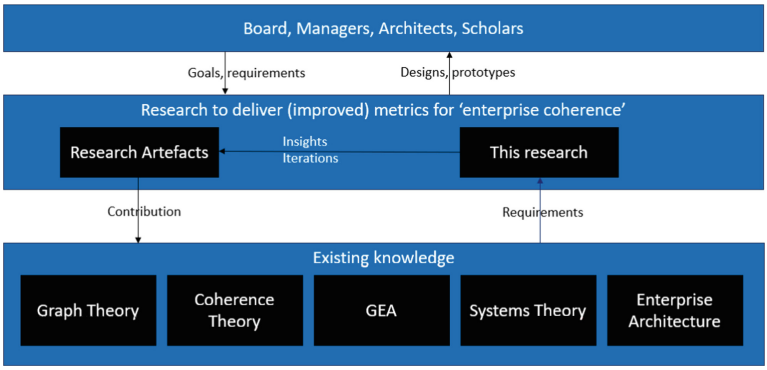

Fig. 2. Quantification of Enterprise Coherence Research positioning (cf. [11])

An important step within the GEA process is the analysis of the ECF [6]. Qualitative analysis goes hand in hand with good quantitative analysis [5]. Quantifications for the GEA ECF however are currently lacking (e.g. [25]). This alone already gives a reason for embarking on this research. Apart from GEA it may be clear that consistency and coherence between various enterprise facets are essential to implement strategic choices successfully [10]. While EA is a means to guide the design and development of the organization and its aspects [4], quantification within EA has not advanced far yet [17]. This research will also add to this area. A survey (yet unpublished research, available on request) indicates that metrics that measure the 'enterprise coherence' will be of value to a target group formed by Enterprise Architects and Senior Management of larger (over 750 employees) organizations. Within the iterative approach proposed for this research we will include validations on usefulness for the target group, e.g. by means of surveys (see Sect. 3.3). The creation of metrics will be based on knowledge from Coherence Theory, System Theory, Graph Theory, Enterprise Architecture, and -as part of the latter- GEA (see Sect. 2).

3.1 Hypothesis

The driving hypothesis is: "*A dashboard can be designed to represent enterprise coherence*".

Apart from design questions on application, usability, interoperability, maintainability, and information security, to name just a few areas, the hypothesis also gives rise to knowledge questions, e.g.:

- What are main concerns on enterprise coherence?
- How is coherence quantified in other domains and why?
- How many metrics would be required to measure enterprise coherence?
- Would it be possible to integrate multiple enterprise coherence metrics into a single index?

These questions will have to be specified and answered in the course of the research.

3.2 Research Goal

The research goal is to deliver a continuously improving information product of enterprise coherence metrics. Goals specific for the social context [11] are:

1. Allow measurement of enterprise coherence.
2. Improve prediction of enterprise performance.

Related design science research goals [11] are:

1. A (set of) enterprise coherence metric(s).
2. A method to arrive at metrics.
3. A system where measurement takes place.
4. Understanding what coherence in graphs of enterprise statements actually means.
5. Being able to predict patterns of coherence in these graphs.

The goal has been achieved if:

- The metrics are defined, and scope and function are described, including effect and sensitivity, and -where relevant- critical values.
- The metrics express the concerns and goals of stakeholders where it regards enterprise coherence.
- The metrics are applications of, combinations of, and/or build on graph measures grounded in literature.
- A practical method for measurement is described.
- A methodology for improving and/or creation of metrics is described.
- Supporting software is available.
- Example practices of metrics and predictions for metrics are given (Fig. 3).

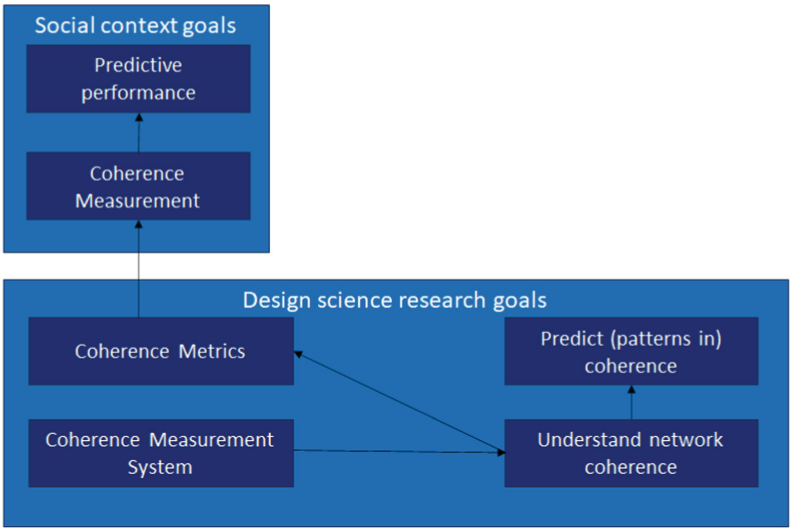

Fig. 3. Goal Structure for the Research (cf. [11])

3.3 Artefacts

We choose to develop in parallel the following artefacts:

1. A set of metrics to measure (aspects of) enterprise coherence. We will call this the Dashboard for Enterprise Coherence (DEC).
2. A graph construct that follows an ontology for enterprise coherence. We will call this graph the Enterprise Guidance Graph (EGG). The EGG starts out expressing basic ontology rules, and iteratively express a more complex ontology, with GEA's ECF ontology as destination. At that point the EGG and ECF will be fully conformant [27].
3. An architecture to import data, perform calculations, and present results in written form and in visualizations (see Fig. 4).
4. A methodology to create and improve the DEC. We will call this the DEC Methodology. As part of the DEC Methodology we will design an Enterprise Coherence Quantification Framework (ECQF) to give guardrails to the development of DEC metrics. The ECQF is elaborated on in Sect. 4.

We develop the DEC Methodology because enterprise coherence is too complex to come up with the right metrics for the DEC right away. Continuous improvement will be needed to be successful. This research will develop the artefacts until the level that others are able to build on further. We will develop a set of metrics to show proof for the methodology, and to allow first measurements to actually take place. All artefacts are subject to design cycles: the DEC Methodology will provide the design cycle for the DEC and the EGG. The architecture will have a design cycle of its own, however we will not explicit elaborate on it, because of its little importance for the research. The DEC Methodology will

also have a design cycle of its own, and we will make improvements on DEC Methodology part of the research. The iterations for the various design cycles may include consultation of the target group to improve decision making.

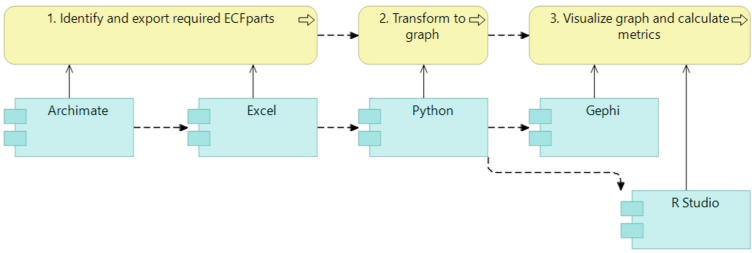

Fig. 4. Current Architecture for the DEC

3.4 Requirements

Requirements are under development. A first set of user requirements has been deducted from a survey among representatives from the target group (yet unpublished research, available on request):

- Being able to compare the effect on enterprise coherence for different architecture design decisions.
- Being able to quantify the impact of strategic change on enterprise coherence.
- Being able to quantify the fit of a solution design based on enterprise coherence.
- Being able to assess the stability of the 'guidance graph' with respect to changes.
- Being able to assess the importance of cross-domain relations.

Apart from user requirements, first sets of (mostly ontology) requirements have been deducted from coherence theory, graph theory, system theory, and GEA. It goes beyond the scope of this paper to describe them here.

4 Enterprise Coherence Quantification Framework

4.1 Enterprise Guidance Graph (EGG)

We define an Enterprise Guidance Graph generically as a set of enterprise statements that can be grouped by certain attributes, and that can have interrelationships. We define an enterprise statement for now loosely as 'a statement that gives direction to a certain aspect of the enterprise', and refer to [6] for more specific definitions for GEA. Enterprise statements and attributes represent the nodes of the EGG (see Fig. 5). Relations between these nodes represent the edges

of the EGG. The relations can be directed or undirected. If it is directed it can be hierarchical or non-hierarchical. A common attribute will be expressed with an undirected relation. We define 'atomic' coherence as the relation between two guiding statements Si and Sj, with Coherence weight equal to Cij. In this way enterprise coherence could be expressed in the adjacency matrix Sij as shown in Fig. 6. The coherence relations determine the further form of the graph representation and will allow to calculate metrics on all kinds of granularity.

Fig. 5. Example of nodes and edges in an Enterprise Guidance Graph (EGG)

ECF	S_1	S_2	S_3	...	S_n
S_1	0	C_{21}	C_{31}	...	C_{n1}
S_2	C_{12}	0	C_{32}	...	C_{n2}
S_3	C_{13}	C_{23}	0	...	C_{n3}
...	...	...	...	...	...
S_n	C_{1n}	C_{2n}	C_{3n}	C_{4n}	0

Fig. 6. Coherence Matrix (adjacency matrix for enterprise statements Si)

4.2 ECQF

Conceptually coherence can be assessed:

1. In the set of guiding statements, i.e. in the EGG.

2. Between the set of guiding statements and solutions.
3. In the set solutions.

The latter becomes visible through the first two, with an assumed positive correlation between them. To make this work, we develop both EGG and ECQF to suit both less refined ontologies as well as GEA, as to allow gradual development. Graphs are typically organized on microscopic, mesoscopic, and macroscopic level [23]. We will follow this setup. We add a layer for 'Solutions' since that is where coherence is supposed to end up. And we will add the aspect of evolution, with the value of being able to analyze and predict coherence patterns over time (Fig. 7).

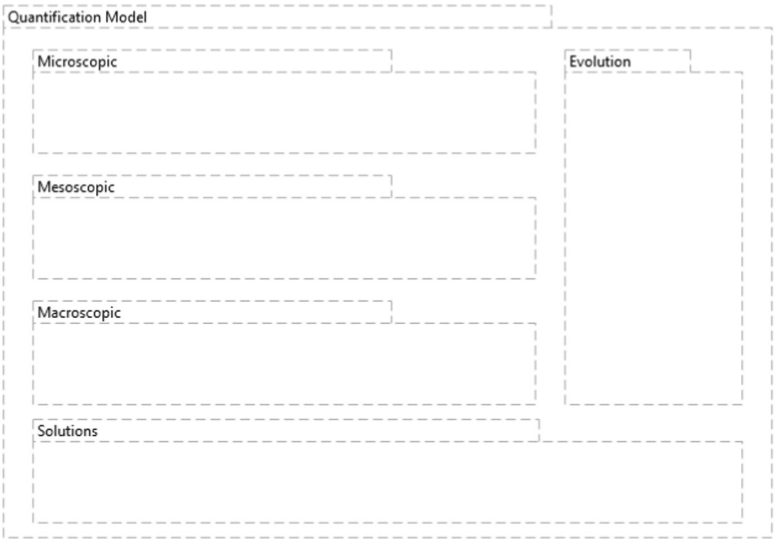

Fig. 7. Enterprise Coherence Quantification Enterprise Coherence Framework ECQF

1. Microsopic level constitutes the study of individual vertices to understand their behaviour. Degree or other centrality measures are typically used [23]. For now we use the term *guiding statement* for any type of statement that directs desirable behavior (including e.g. references to used models).
2. Mesoscopic level concerns the study of modules or community structure. Modules are formed by corresponding properties of nodes described by undirected relations. Modularity is an example of a general metric for community quality and for community detection algorithms [19], and e.g. associated with limiting unnecessary complexity in systems [15]. This way GEA's 'perspective' and 'level' could be expressed.
3. Macroscopic level classifies the global structure of the graph. E.g. hierarchical structure is pervasive across complex networks with examples spanning

from neuroscience, economics, social organisations, urban systems, communications, pharmaceuticals and biology [23], and it is shown that hierarchical coherence [23] is a proxy for stability. A set of guiding statements is most often hierarchical in nature ('tree'-like), although not per se perfect, and multiple trees may exist.
4. We define a solution element as a (foreseen) (part of an) implemented solution. A solution element will be coherent with a guiding statement if it contributes to its intent. Contribution of a set of solution elements can be measured, as shown earlier [22].
5. Business practice changes guiding statements, directly or through a 'domino-effect' (see e.g. [7]. We will introduce an evolution model that allows for modeling behavior and predictions in a later stage of the research.

5 Single Case Experiment

We use a single case experiment with realistic conditions and expert opinion. This is to understand first behavior of the developed model in practice, and to weed out bad design parts early [11].

We want to be able to measure figures conform the ECQF that make sense for analytical purposes. And we expect figures to follow systemic behavior. This leads to the following hypotheses:

1. For microscopic, mesoscopic, and macroscopic level of the ECQF sensible -though maybe not ideal- measures can be found.
2. Measures show explainable results.
3. Systemic behavior can be demonstrated.

We will use these metrics in an experiment to prove that the ECQF setup is plausible. As Object of Study (OoS) we take results of a fictive case that is used in GEA trainings, about a supermarket that needs to survive several changes. Coherence calculations need to add value to coherence analysis. An ECF has been put together for this case in several steps, whereby, the normal GEA practice [25] was followed:

1. Initial Level of Purpose, with relations Mission-Vision, Mission/Vision-Core Values, Mission/Vision/Core Values-Goals, and Goals-Strategies. We will call this *LoP1*.
2. New Level of Purpose, based on discussions. We will call this *LoP2*.
3. Level of Design, including relations Goals-Objectives, Core Values-Principles, and Strategies-Policy. We will call this *LoPD1*.
4. New Level of Design, based on discussions. We will call this *LoPD2*.

We need concrete metrics to be able to validate the abilities from the previous subsection. As preliminary metrics we used measures that have been used extensively in other domains, and that have a thorough mathematical grounding. Together they cover to a broad extend the currently defined ECQF:

1. For microscopic level centrality measures we will use coherence weighted degree and PageRank [1]. The first because it allows easy interpretation due to the direct relation with coherence definition on 'atomic' level (see Sect. 4). The latter because PageRank gives a more advanced view in the relative importance of the various nodes. Although other centrality measures may be good candidates too, the broad acceptance of the proposed measures makes them acceptable first candidates.
2. For mesoscopic level community structures we will use modularity (e.g. [3]) and smallworldness [2,26] as first measures. Modularity expresses a preferred way of coherence known from software architecture (e.g. [16]) and from other systems (e.g. [13]. Smallworldness expresses modularity and integration in a single measure. Smallworldness has also been researched extensively [26].
3. For macroscopic level hierarchical coherence we will use hierarchical incoherence [23], which we return as hierarchical coherence by subtracting from 1. Other hierarchical measures may be researched later.

Based on the fact that the events described in the previous subsection were intended to be improvements on the ECF, we expect an increase of:

1. coherence weighted degree
2. modularity
3. hierarchical coherence
4. smallworldness
5. a power law for PageRank values, due to increasing system effects along with size.

The experiment has been carried out in various sessions. Coherence calculations were done afterwards, so the outcome did not influence the decisions. The excels were filled in by the Core Team on the various events and graphs were created. The quantitative results for the measures coherence degree, modularity, hierarchical coherence, and smallworldness are shown in the tables below for the Level of Purpose, and for the combined Level of Purpose and Level of Design. We normalized all figures against the highest value to come to the radar (see Fig. 9).

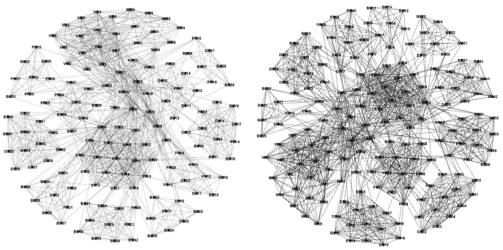

Fig. 8. Visual comparison of LoPD01 (left) and LoPD02

The results for PageRank where used to assess systemic behavior. PageRank was calculated using the directed edges only for LoPD2, i.e. the entire graph in the end situation. The results are shown graphically in Fig. 9.

Metric	LoP1	LoP2	Increase (%)
Coherence degree	8.6	11.8	37%
Modularity	0.3	0.4	46%
Hierarchical coherence	0.6	0.6	−3%
Smallworldness	1.6	1.7	6%

Metric	LoPD1	LoPD2	Increase (%)
Coherence degree	28.5	30.4	7%
Modularity	0.36	0.40	10%
Hierarchical coherence	0.01	0.11	56%
Smallworldness	0.67	0,68	2%

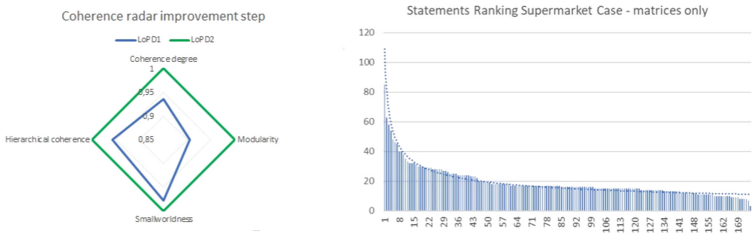

Fig. 9. *Coherence Radar for improvement* and *PageRank showing power law*

6 Conclusions and Discussion

The results for the measures coherence degree, modularity, hierarchical coherence, and smallworldness showed an increase for almost all coherence measures, in line with expectation. There was a decrease in hierarchical coherence for the level of purpose, but it was very small. Graph visualizations (see Fig. 8) show differences in concentrations in the graphs, that apparently go together with different coherence values. The results for the measure PageRank which we used to validate systemic behavior showed a clear power law. We conclude a positive indication that the used metrics show coherence improvement. An interesting additional result was that visualizations seem indicative for the quantitative results.

For the overall experiment hypotheses we conclude:

1. For microscopic, mesoscopic, and macroscopic level of 'Quantification' sensible -though maybe not ideal- measures can indeed be found.
2. Systemic behavior can indeed be demonstrated.
3. The parts *microscopic*, *mesoscopic*, and *macroscopic* of the ECQF where of use as container for the preliminary metrics.

7 Limitations and Further Study

Since this is a new field in enterprise architecture, there were clearly limitations in both preliminary model and practical application. The coherence figures were not yet comparable with other cases, which makes plausibility and significance more difficult to assess. Although the results show correlations that support our hypotheses, mechanisms are yet unexplained. In follow up research we will look at how to address this with the use of synthetic graphs. This is a threat to validity. Also, the preliminary measures should be regarded as 'minimal viable product'. Furthermore, to properly support the ECF, the ECQF should include a framework for evolution. Finally, additional real life cases are necessary to allow better comparison for insights into the behavior of the ECF graph and its metrics.

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