# Integration Between Star Model Components for Project-Based Organizations Design: a Network Analysis

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## Abstract
Star Model is a framework for organization design and has been highlighted for its completeness and holistic perspective. Star Model has also been adapted to Project-Based Organizations' (PBO) design. Some researchers have chosen this guideline considering the connections and interdependence between its five components: Strategy, Process, Rewards, Human Resources and Structure. However, to the best of our knowledge, there is no quantitative viewpoint about these connections in the literature yet. In this paper, the interconnections between the Star Models' components are modelled, measured, and analyzed using the Network Analysis (NA) tool. NA is a technique that predicts the structure of the relationships between entities and uses graph theory to deploy its connections through mathematical indicators. The results confirm that all Star Model components are linked effectively, although at different levels, and that some components are the bridge for maintaining their relationships. This research seeks to provide a management tool for project managers and organizational analysts, giving quantitative support for effective organizational design and implementation.

## Keywords
Star Model, Project-Based Organizations (PBO), organization design, project management, Network Analysis (NA).

## 1. Introduction
Organization design focuses on the different organizational forms, strategic choices for managers and the external and internal factors affecting them (Miterev et al. 2017). Oganizational design has also been studied to improve business performance (Rovelli and Butticè 2020). In this context, Project-Based Organizations (PBOs) are organizations in which projects are the main business process for coordinating and integrating their business functions (Loufrani-Fedida et al. 2015). The study of PBO has received attention from researchers during the last ten years (Cattani et al., 2011) and from different study perspectives. For instance, the continuous improvement of PBO (Backlund and Sundqvist 2018), the information technologies that support the project management into a PBO (Abrante and

Figueiredo 2021) and also PBO design (Miterev et al. 2017). Regarding this last field, several studies have been developed in order to propose a guideline for designing PBO and focusing on specific aspects such as governance (Turner and Keegan 1999), and operations management (Turner and Keegan 2000) and human resources (Huemann et al. 2007). However, a current concern regarding these guidelines is the integration and interrelation of these design aspects and a proper approach to ensure these guidelines' applicability (Miterev et al. 2017. a). In response, the Star Model for the PBO design framework has been proposed (Miterev et al. 2017. b). This proposal is an adaptation of the Galbraiths' Star Model guideline, in which the fundamental idea is the alignment of design components (Galbraith 2007). Star Model considers the interrelation between five interconnected components: strategy, process, rewards, human resources, and structure. Each component raises the following questions for the organizational designers:

- Strategy: What is the success formula?
- Structure: How are we organized? What are the key roles? How is the work managed? Who has the power and authority?
- Process: How are decisions made? How does workflow between roles?; What are the mechanism for collaboration?
- Rewards: How is a behaviour shaped by the goals? How do we assess progress?
- People: What skills are needed? How do we best develop our talent?

The design components can be detailed into sub-components, and these elements could affect other components; for instance, the strategy contains the company's vision, mission, and organizational capabilities. This last component is related to people skills needed to achieve organizational goals. Thus, the relationships between components can be established and modelled as components and relationships are identified. Understanding these relationships could be useful for giving a quantitative overview to the organizational designers regarding the level of connection between components and clarifying where these links occur. Also, the measure of these relationships could be a tool for design verification: the designed elements and their relationships should be related to the number of elements and level of interconnections pre-established in the framework. However, the modelling of the concepts, relationships, and measures has not been studied yet in the literature.

This paper seeks to propose a model and measure of the Star Model framework using the Network Analysis (NA) approach. NA is a technique to represent the relationships between actors and the structures appearing with the recurrence of these links. The analysis is developed by collecting relational data in a matrix form (Chiesi 2001). This technique has been widely applied and used as a tool for organizations to understand its complexity and systems, identify knowledge leaders in organizations, measure collaboration of teams, the pattern of changes, structure and interactions (Daim et al. 2016; Pan et al. 2017). In the project management field, NA has been applied to understand the integration level of PMBOK processes through modelling its structure: input, tools, techniques and outputs (Herrera et al. 2020). This article takes this work as a basis for studying the level of integration between the components of the Star Model.

The rest of this paper is structured as follows: Section two describes the research method based on the NA technique. The results and discussion are developed in section three.y Section four contains the conclusions obtained through this research.

## 2. Research Method

This paper follows the research method described in Figure 1, consisting of two stages: Stage (1) identifies Star Model concepts by reading and extracting concepts and relations.

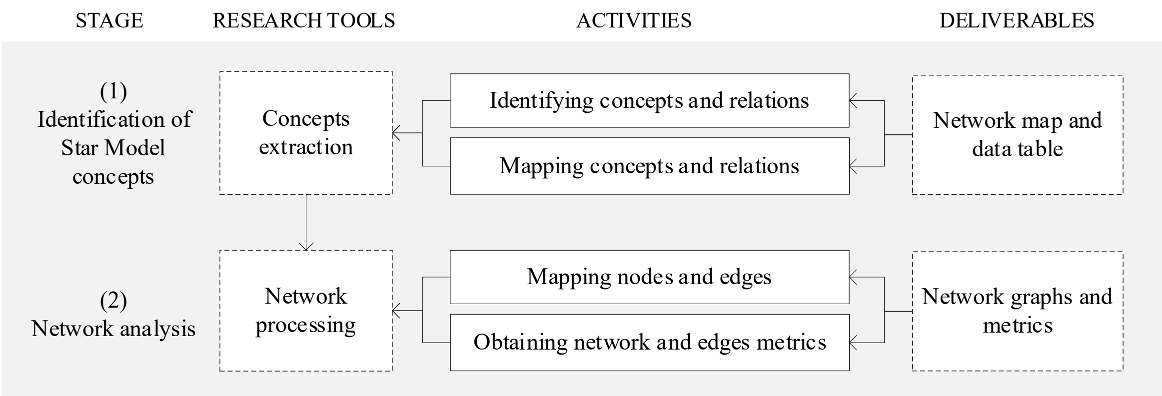



Figure 1. Research method.

These extracted elements are mapped using the Kumu.io© editor for systems modelling. This application allows exporting the model into a data table, which is then imported and processed at Gephi©[1] software for NA.

In stage (2), the network analysis technique is applied – using Gephi - to obtain this method's two fundamental components: nodes and edges. Nodes are points where information entry or exits, and edges are the links between two nodes representing the information flow. Nodes and edges allow the development of a graph to be analyzed through metrics (Herrera et al. 2020). These metrics are detailed in Table 1 and Table 2.

Table 1. Network metrics (Cherven 2013).

| **Metric** | **Description** |
|---|---|
| Density | The number of links between nodes divided by the number of total possible links reflects the networks' cohesiveness |
| Average degree | The average number of connections that each node has within each network |
| Diameter | The largest of the shortest paths between every pair of nodes |
| Average path length | How many steps, on average, do nodes require to reach each other |
| Modularity | How dense connections are between nodes within groups compared with other groups |
| Clustering | Measures how clustered groups of people are compared to the rest of the network, indicating the existence of closed triads and small communities |

Table 2. Nodes metrics (Cherven 2015).

| **Metric** | **Description** |
|---|---|
| Indegree | This measure tells us how likely other nodes are to seek out a single node, whatever the attribute that makes this member an attractive target for others |
| Outdegree | Defined as connections flowing from a selected node to a range of other network members |
| Weighted indegree and outdegree | The degree is related to the sum of weights when analyzing weighted networks and labelled node strength, so the weighted degree and the weighted in- and outdegree were calculated |
| Eccentricity | Refers to the number of steps required for an individual node to cross the network. The diameter of the graph limits this number |
| Closeness centrality | This metric represents an interesting case, wherein the selected node might be poorly connected in a direct sense yet is still highly influential due to the proximity of well-connected neighbours |
| Betweenness centrality | Betweenness centrality corresponds to the level at which any given node serves as a bridge connecting other nodes |

[1] https://gephi.org/

| | |
|---|---|
| Clustering | Provides the ability to measure the level at which the nodes are grouped, as opposed to being equally or randomly connected across the network |

## 3. Results and Discussion

In the following section, the results of the NA application are explained. As indicated in the previous section, the main concepts and relationships were obtained by reading and mapping in a model editor, and the resulting first model is shown in Figure 2.

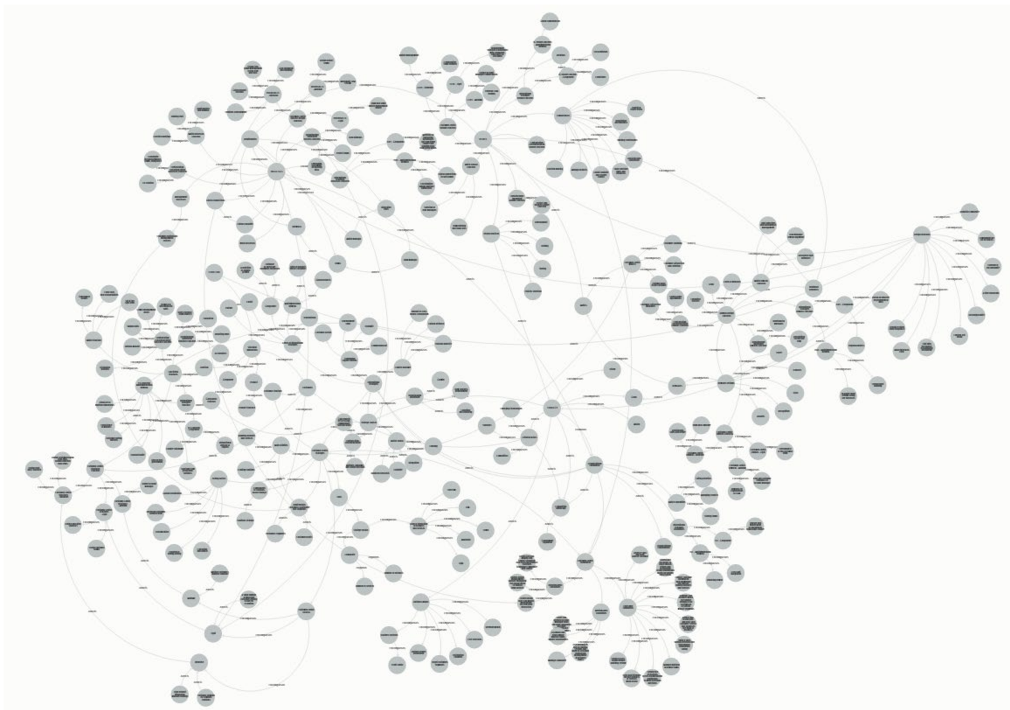
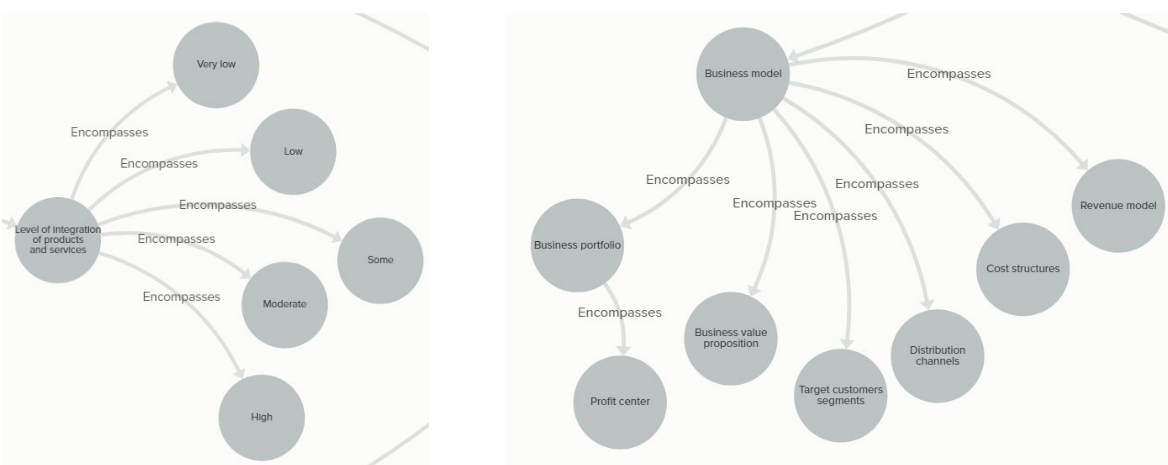


Figure 2. Resulting model using kumu.io.

The concepts can have two types of relationships "encompasses" and "affects". The first connections type is related to a correspondence between classes and sub-classes or components interrelated into a context. Figure 3-a shows an example of relationships between class-subclass. Figure 3-a illustrates how an organization's business model encompasses a group of related components.




(a) (b)

Figure 3. "Encompasses" relationship type between concepts.

These relationships were modelled as directed edges. These edges are applied between nodes, with a starting node to an ending node, in one direction. The "affects" relationships are related to concepts that have some influence on others. Figure 4 shows how the external factors – that encompasses other concepts – "affects" the strategy.

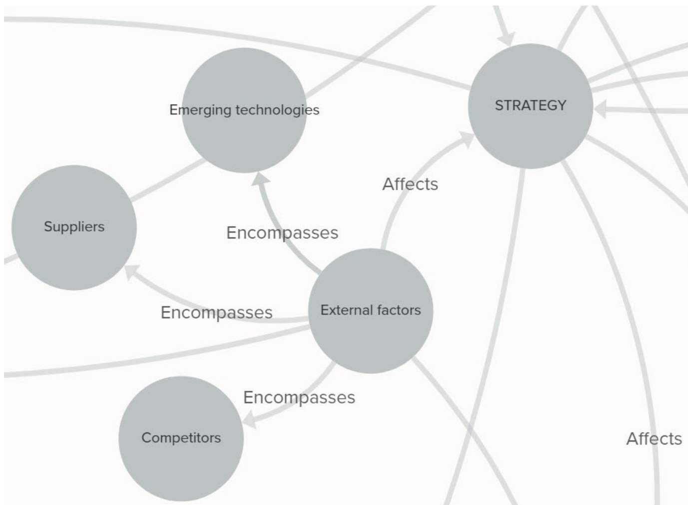



Figure 4. "affects" relationships type between concepts.

All the concepts mapped were labelled with a Star-Model component according to the context from which the concept was extracted in the text and the relationship to the component.

The model analysis was conducted from two perspectives: (1) the network analysis with all concepts classified regarding the five Star Models' components and (2) the study of the intrinsic relationships between concepts (excluding the labelling of the concepts regarding the five components of Star Model).

## 3.1 Network analysis using Star Model concepts classification

All concepts of the Star Model framework and their relationships were exported from kumu.io and imported into Gephi for the network analysis, as shown in Figure 5. This graph previously classified concepts regarding the Star Model component (Strategy, structure, people, rewards, process) and a transversal group called "principles". The above relates to the design principles described and applied for all Star Model components. The nodes represent the concepts identified, and the edges are the connections between them. As shown in Figure 2 below, the strategy component has the main number of nodes. The rest of the components have a homogeneous percentage of nodes. Additionally, the strategy group occupies a central place in the whole network, connecting the rest of the groups. This proportion relates to the importance of the strategy component described in the Star Model framework, in which *"the organization strategy is the cornerstone of the organization design process…if you do not know where you are going, any road will get you there"* (Galbraith, 2007).

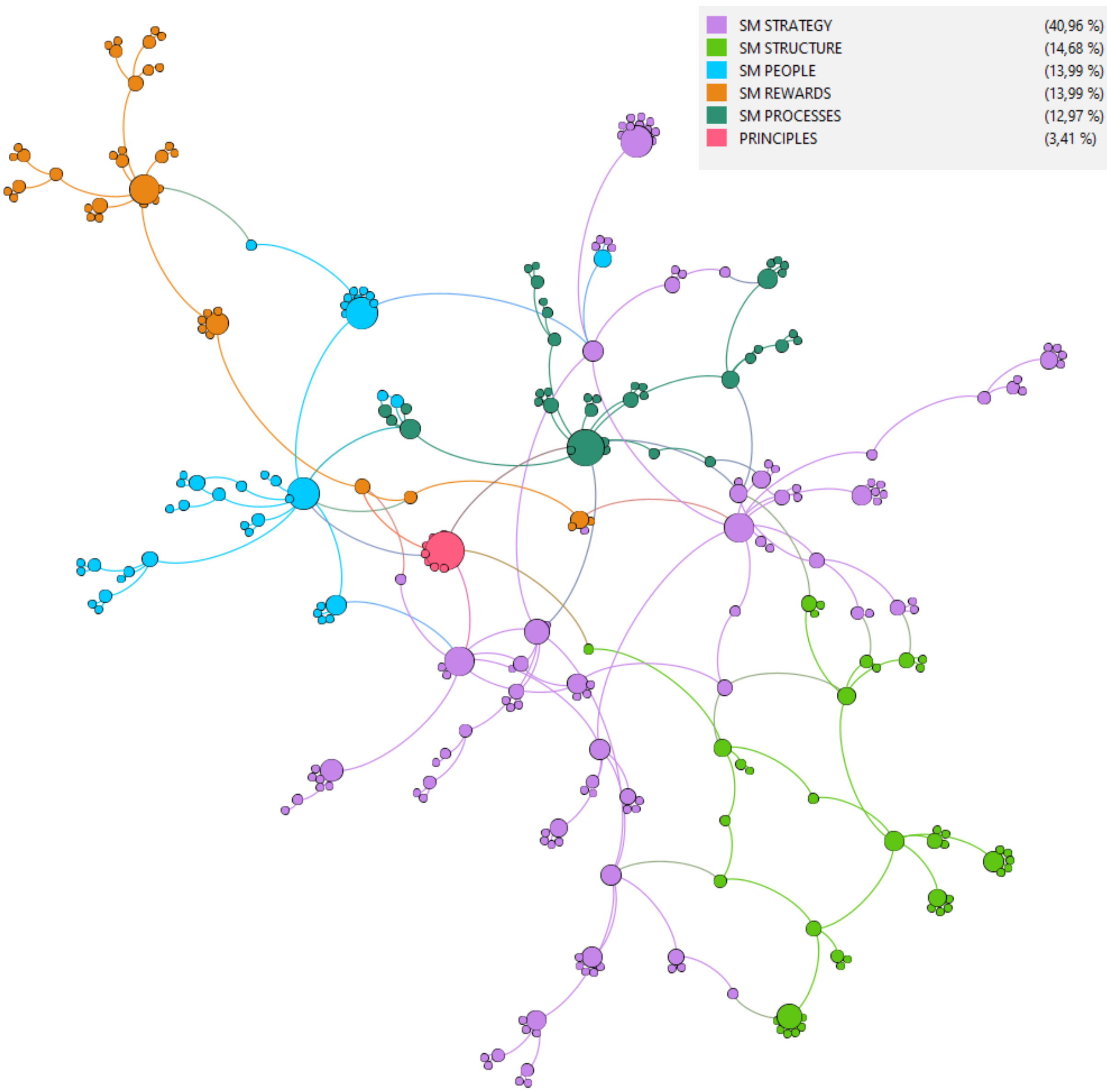



Figure 5. Graph with Star Model concepts and their relationships.

All the nodes of the model are connected. The above is confirmed by the metric "connected components" with a value equal to 1, i.e., all the concepts make up an interconnected block. The node size is related to the degree (the connections in and out of each node), and their values vary between a minimum of 1 and a maximum of 14. As shown in Figure 6, 183 of 293 total nodes have at least one connection with the network. However, this could represent a weakness in the level of cohesion of the network since it is enough to break a link, and part of the network could be disconnected.

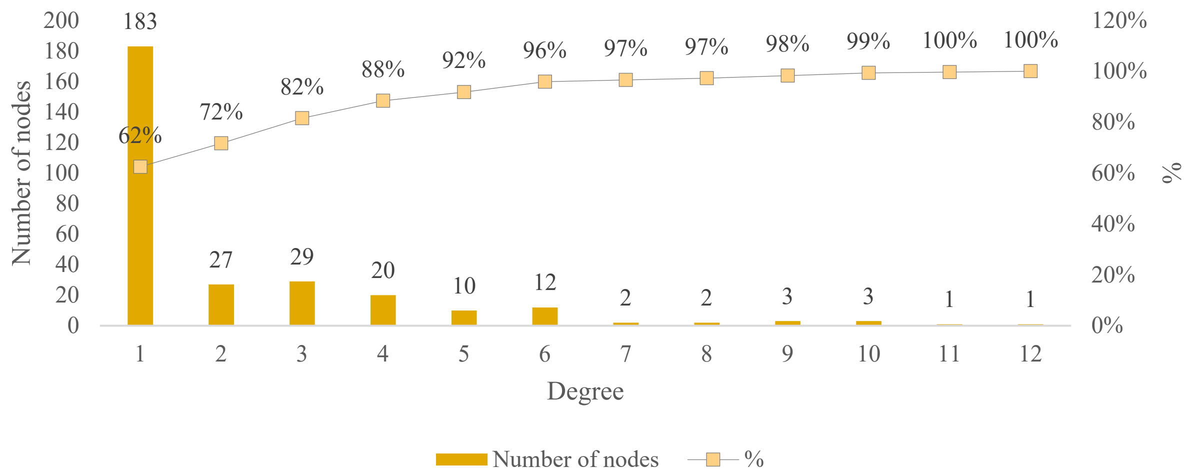


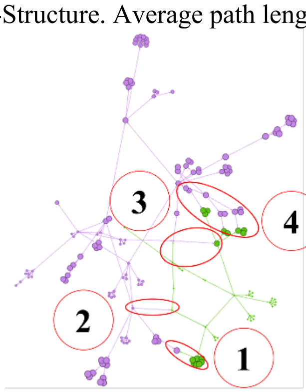
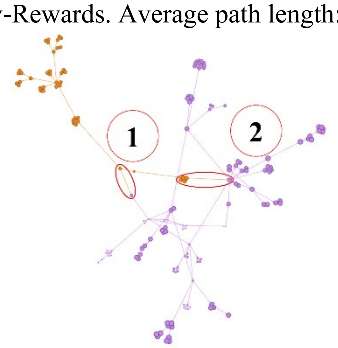
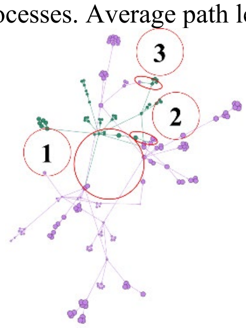
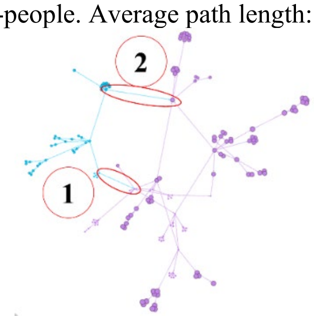

Figure 6. Frequency of degree.

The interconnection between the components of the Star Model as a group of nodes is possible to identify using NA. Figure 7 shows the relationships between the strategy and Star Model's rest components.


Figure 7: Strategy connection with the other Star Models' components.

As shown in Figure 7, the Strategy component connects all Star Model components, binding the whole network. The importance of the strategic definitions for interoperability between the different organizational dimensions is then highlighted. The connection between strategy with other components is obtained through nodes working as a bridge. These bridges are summarized in Table 3 below.

Table 3. Nodes connecting strategy components with others.

| **Components** | **Bridges (from strategy to other components)** |
|---|---|
| Strategy-Structure. Average path length: 3,014<br><br> | 1) Node "portfolio diversity" regarding the power distribution structure between geographic and business units and the "strategic multidimensional network concerns" node for global-scale management.<br>2) Node "international strategies" and "geographic structure". This connection describes how the strategy sets up operations outside the home country.<br>3) Node "customers" with "structural dimensions" and "customer-centric structural concerns". This relationship consists of the intensity of customer-centric focus for structuring the organization.<br>4) Nodes of the degree of intensity of strategy (light, medium and intensive) with the corresponding structure. |
| Strategy-Rewards. Average path length: 2,939<br><br> | 1) Node "goals" with the general node "rewards", showing how goals are disseminated throughout the organization to finally reach the reward structure of its employees.<br>2) Node "customer-centric strategies" with "customer-centric metrics". |
| Strategy-Processes. Average path length: 2,668<br><br> | 1) Nodes "organizational capabilities" and levels of customer-centric strategies arriving at the main process node.<br>2) Node "Relationships customers profitability and segments" from strategy group with "Customer relationship management process".<br>3) Strategic node "Create pricing rules and market mechanisms for front-back interaction" with the level of intensity of customer-centric processes. |
| Strategy-people. Average path length: 2,777<br><br> | 1) The"strategy" node ( is connected with "people practices."<br>2) Node "customer-centric capabilities" with "competencies." |

As shown in Table 3, the average path length (APL) is calculated. This metric describes the number of steps, on average, nodes require to reach each other. Studying the relationship between strategy and the other components, the APL is similar, reaching a close to 3 value. The shortest APL is displayed between the pair strategy-people.
Removing the strategy component from the map, it can be seen that other components lack connections between them as a group. As shown in Figure 8, some components would not directly relate to others if the strategy did not represent a bridge between them. This unexpected result questions the Star Model's main statements about the interrelationship between its components and implies the need to look for possible implicit connections in Galbraith's text.

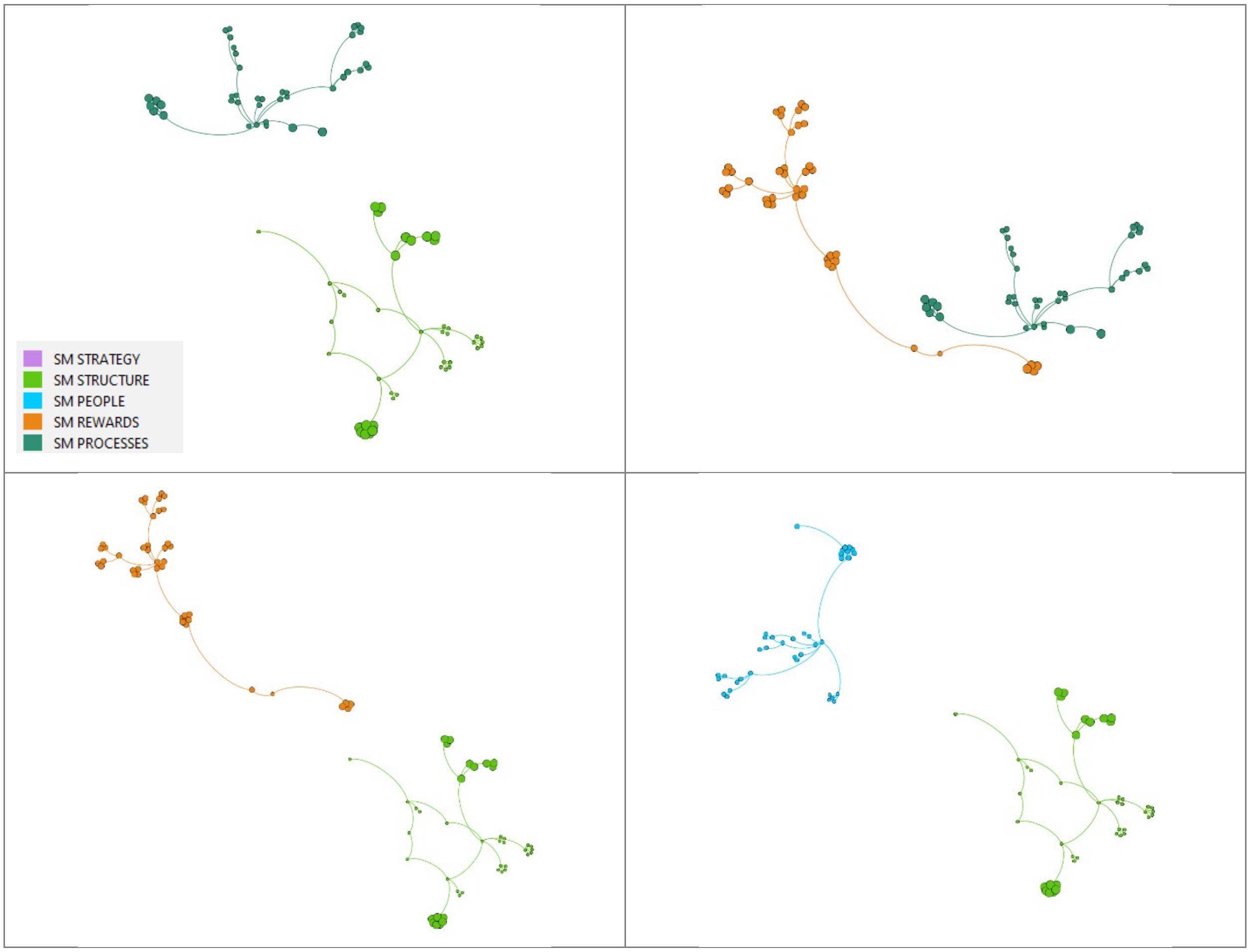



Figure 8. Components with no connections between them.

## 3.2 Network analysis without using Star Model component labelling

NA allows analyzing the intrinsic relationships between elements. This analysis is developed by leaving the labelling used in the last section. Figure 9 shows that 16 clusters are constituted regarding the modularity metric of the network, with a value of 0,821. This value measures the force of networks' division in groups and the level of connection between nodes of each group. The obtained value is close to the maximum level (1) and indicates a strong connection of the nodes into a cluster.

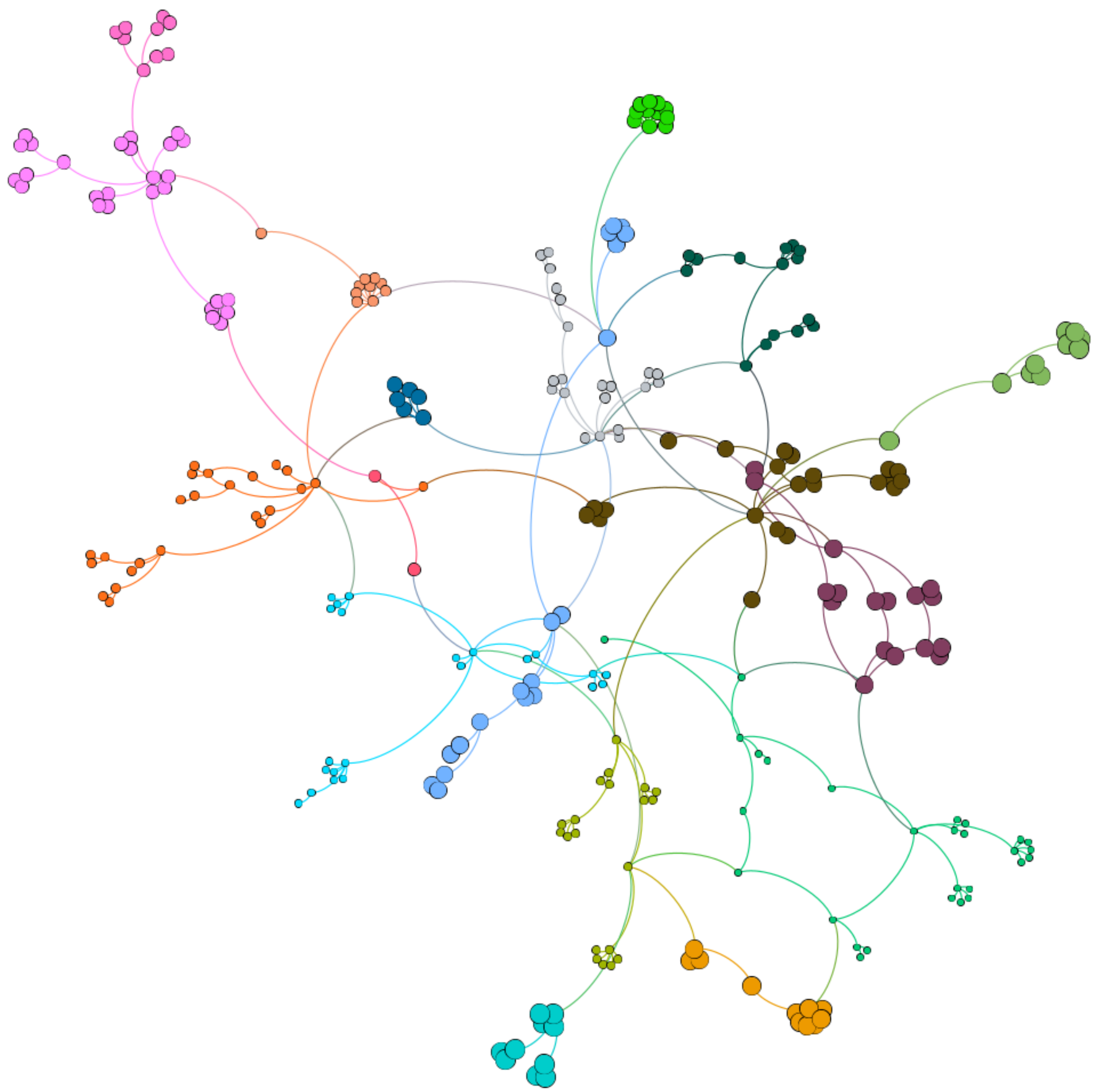


Figure 9. Composition of clusters between the different nodes of the Star Model.

Superposing the 16 conformed clusters with the groups obtained in Figure 5, a new overview of the network is presented in Figure 10. As shown in the figure, the initial groupings (according to Star Model component labelling) are partly maintained as well as subdivided into other clusters. The above also generates sub-clusters that go beyond the boundaries of the Star Model, for example, clusters orange (1), light blue (2) and brown (3).

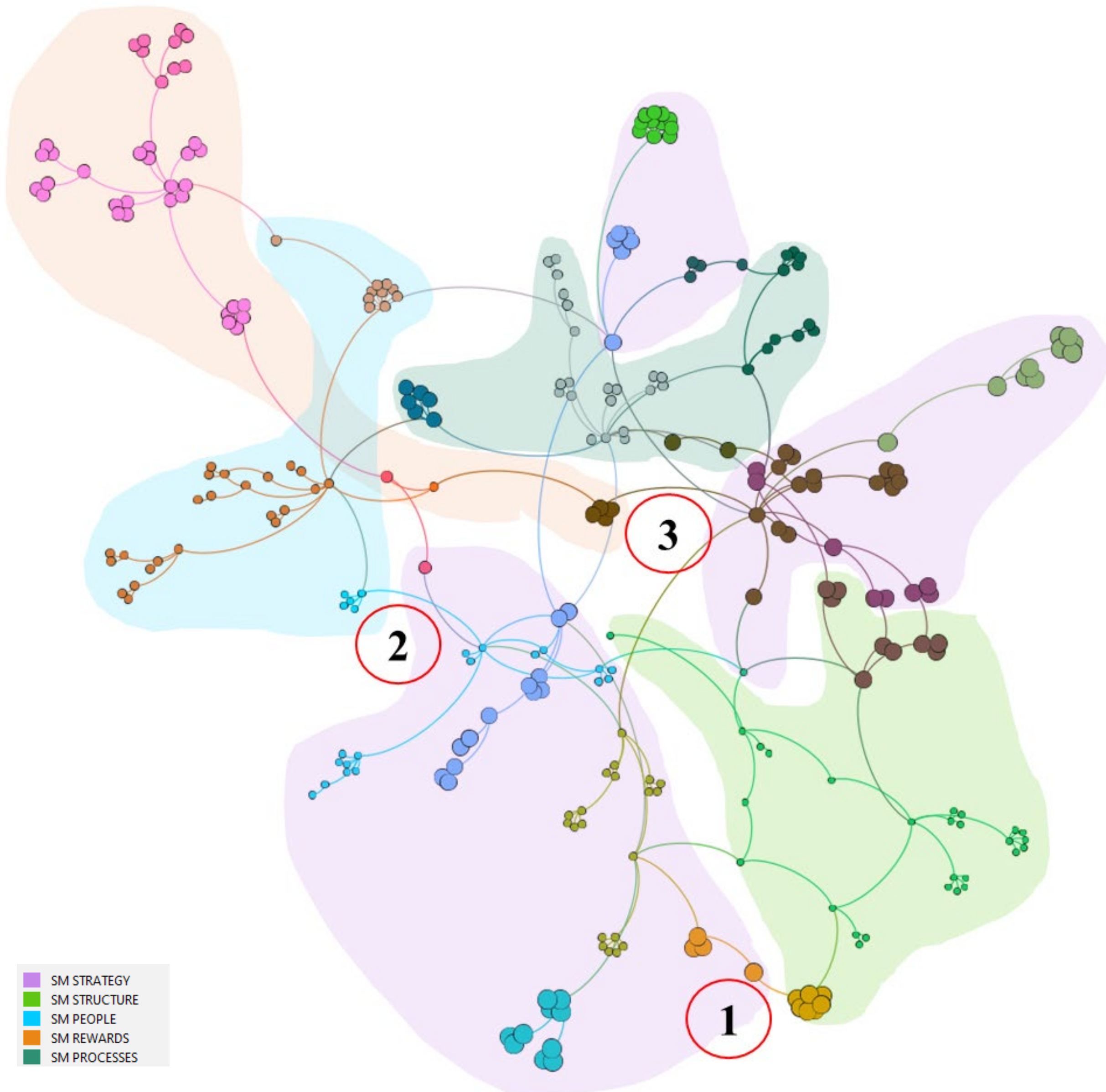



Figure 10. The clusters obtained regarding the modularity metric.

The network can be analyzed regarding its NA metrics. Figure 11 shows the metrics obtained and a graphic representation for betweenness centrality (1), closeness centrality (2), clustering coefficient (3) and eccentricity (4).


Figure 11. Networks metrics obtained and their graphic representation.

Regarding Figure 11-1, it can be seen that almost 71% of nodes have a value equal to zero. This value means that this node does not serve as a bridge for another node to connect to others. This situation is due to the modelling method used, where the nodes are mainly deployed in the form of branches that open up into class relations and subclasses. Other implicit relationships could be identified in Galbraith's text for modelling other edges.

Figure 11-2 shows the closeness centrality metric and its graphic representation. This metric represents the sum of the shortest paths between a node and others. 61,43% of nodes have a zero value, which means the nodes are not strongly connected. 24,57% of the nodes have a value of 1 (good level of connection), and the rest have values between zero and one.

Regarding the clustering coefficient (Figure 11-3), 94,2% of nodes have a value equal to zero, meaning a low degree of clustering. Three nodes reach a value of 0,5 and the rest, between zero to 0,5.

The eccentricity metric is displayed graphicly in Figure 11-3. This metric relates to the minimum steps required for any node with a maximum value equal to the network's diameter (value equal to 9). 61,43% have a value equal to zero.

Table 4 and Table 5 summarize the metrics obtained for all networks—the density value close to 0 means separate nodes, and the one value is a dense graph. The value of 0,004 indicates that the nodes are not well cohesive and dispersion among them. The average indicator degree has a value of 1,02 and reflects the average links between each network node. The network's diameter equals 9, meaning that one concept is nine nodes of distance to meet with others as the maximum distance. This value also reflects that the nodes are not very close between them.

On the other hand, the value of the average path length indicates that each node requires 3,486 paths to meet the other node. Modularity indicates the level of connections between nodes conforming to a cluster. Considering a maximum value of 1, the value of 0,81 shows a high density of connections into a cluster.

Table 4. SNA metrics.

| **Metric** | **Value** |
|---|---|
| Density | 0,004 |
| Average degree | 1,02 |
| Diameter | 9 |
| Average path length | 3,486 |
| Modularity | 0,81 |
| Clustering coefficient | 0,01 |

Table 5. Average and standard deviation for SNA metrics.

| **Metric** | **Average** | **Standard deviation** |
|---|---|---|
| Indegree | 1,102 | 0,67 |
| Outdegree | 1,02 | 2,06 |
| Degree | 2,204 | 2,17 |
| Eccentricity | 0,87 | 1,58 |
| Closeness centrality | 0,30 | 0,42 |
| Betweenness centrality | 17,68 | 52 |
| Modularity class | 7,39 | 5,27 |

# 1. Conclusions

The main reason for the Star Model's choice as a framework for PBO is the wide coverage of dimensions (five components) and their interrelation. This framework has been modelled, measured and analyzed in this article. It has been verified that all components of the Star Model compose a network, and their components are connected. However, it can be seen that some components are not directly connected and are only linked through a bridge represented by the strategy component, which allows the whole network's interrelation. Moreover, the connections that allow the relationships between the strategy component and others were identified. The results of the present analysis reaffirm the importance of the strategy for this framework and how this component gives the guidelines for the whole organization.

Studying the intrinsic relationships between all nodes, 16 clusters are formed, mainly as a subdivision of a Star Model component. Although the model obtained presents a similar form to the model with labelled components, it confirms the concepts' closeness with its main Star Model's component. It can also be verified that some clusters cross the components sharing concepts.

In general, the network is completely connected but has no strong cohesion. Some specific nodes are important for maintaining the relationship between Star Model components and work as a bridge through the strategy component. Some of these nodes are, for instance, the international organizational structure (from structure Star Models' component), goals (rewards), customer processes (process) and people practice and competencies (people).

This paper seeks to be useful for organizational analysts and designers to facilizing the use of the Star Model as a guideline. On the one hand, the main concepts of this framework were modelled, and it is possible to navigate with a simple query in the Kumu.io© application used. On the other hand, the key connections of the Star Model components were identified, providing insights to the analysts so that these connections are effectively embodied in the organizational design to ensure complete interrelationship. The connection levels found in this work could be used as a reference level to measure the level of adherence to the Star Model as well as the level of interconnectedness of PBO components modelled. It can also be considered that a quantitative basis on a standard (such as PMBOK, for example) can help to build an organizational maturity model on some practice, such as OPM3 for organizational project management.

Future studies may be focused on finding implicit connections between the nodes, reveal new interdependencies, and increasing the degree of cohesion between the Star Model principles.

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## Acknowledgements

Thanks to the TIMS professors, Rodrigo F. Herrera and Felipe Muñoz-La Rivera (Technology, Innovation, Management and Sustainability) of the Pontificia Universidad Católica de Valparaíso for the continuous support and development of ideas that have been taking the form of articles and from which the present work arises. We are grateful to our POLIMI PhD colleague Sara Bossi for her support in the English proofreading of this manuscript.

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