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# Summary of “Characterizing Value Chain Patterns of Urban Factories using Principal Component Methods and Hierarchical Clustering on Principal Components: A Case Study in the Grenoble Urban Area”

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## Abstract

This summary presents results from the paper “**Characterizing Value Chain Patterns of Urban Factories using Principal Component Methods and Hierarchical Clustering on Principal Components: A Case Study in the Grenoble Urban Area**” which has been submitted to **Journal of Cleaner Production** and is still in the review process. In this paper, a characterization methodology has been proposed and applied on a case study in the Grenoble urban area in which 46 different value chains of urban factories have participated. This has been conducted using a multiple factor analysis (MFA), a principal component analysis (PCA) and a hierarchical clustering on principal components (HCPC). Clustering has resulted in the definition of 16 different patterns. The proposed methodology can be used on other urban areas to support designers in characterizing patterns for urban factories based on value chain models of successful urban factories.

**Keywords:** urban factory; value chain; characterization; principal component methods; clustering

## 1. Introduction

To mitigate environmental impacts and re-localize manufacturing systems back to urban areas, the sustainable concept of urban factories was introduced in 2016 [1]. These refer to factories located inside an urban area and that utilizes proximity to resources and stakeholders throughout its value chain to create value locally [2]. Many types of urban factories can be designed. A macroscopic screening of the value chain has resulted in defining urban factories that either utilize their proximity to local suppliers at the inbound logistics and procurement level, or to customers at the outbound logistics and marketing levels, or at both at the same time [3]. Porter’s value chain model presents an extensive structure of both primary and secondary activities that are required to bring a product with an added value from conception [4]. Each activity can help characterize an urban factory’s value chain with various qualitative and quantitative variables such as quantities, sizes, and types. In the previous step of this research project, a limited number of variables have been extracted from an extensive systematic literature review on urban factories, and a cross-analysis with Porter’s value chain model [5]. In addition to the multitude of these variables, urban factories have been integrated to their urban environment which has also been characterized by many variables such as local policies, infrastructures, and market sizes [6]. To overcome such complexity for engineering designers of urban factories resulting from the big number of variables relative to the ‘value chain-urban area’ system, a quick and effective pathway would be to investigate feasible and sustainable value chain patterns from existing urban factories in the same urban area. Urban factories have not yet been subject to similar systemic thinking in the design of framework specific best practices to support engineering designers. It is for this purpose that the present paper aims to answer the following research question: which value chains patterns are the most adapted for urban factories in their urban area?

## 2. Methodology

To answer the research question presented in the previous section and overcome the systematic nature of value chains and urban factories, a research methodology in 5 steps has been designed as presented in Fig. 1.

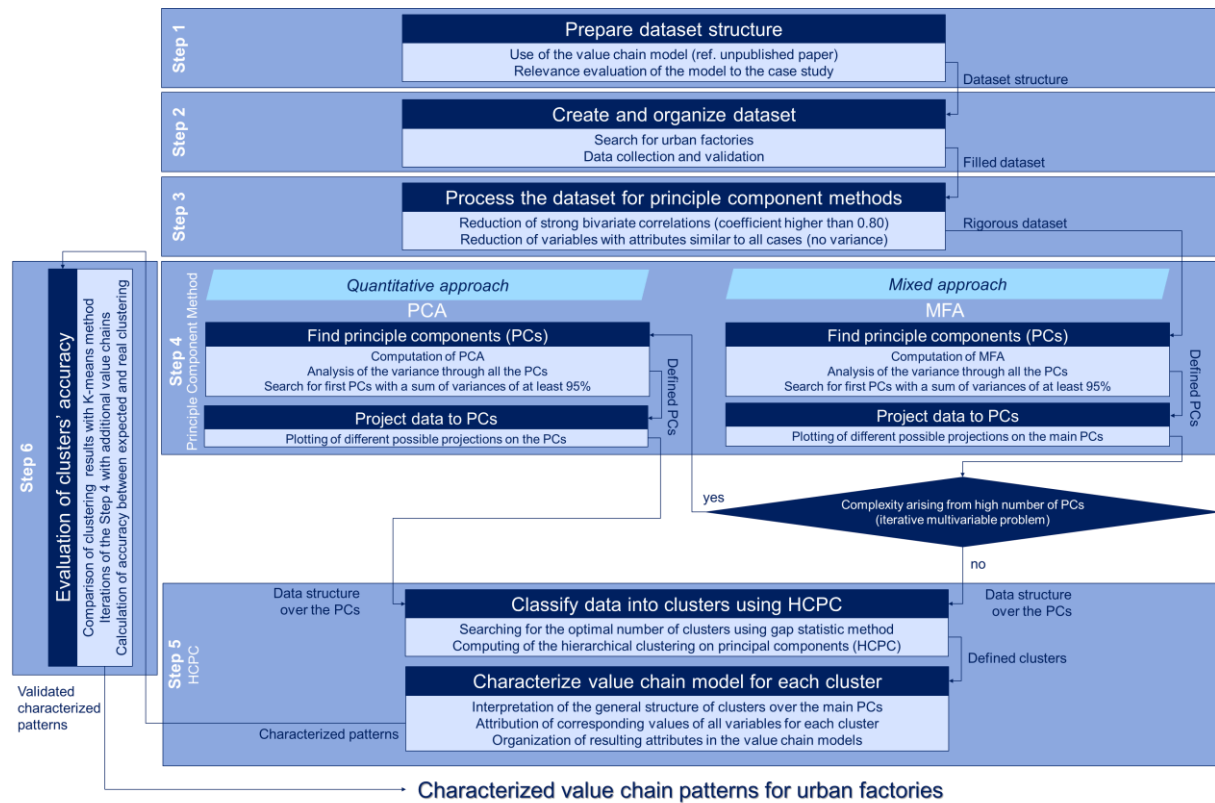


Fig. 1. Research methodology used in the paper.

Firstly, an initial step in which a structure for the dataset has been prepared using Porter's value chain model as presented in step 1. Secondly, urban factories from the Grenoble urban area have been identified and contacted to participate to the case study following a meticulous search protocol as presented in step 2. In this step, data from the urban factories has been collected under the same structure of the previous step, and validated to result in a filled dataset. Thirdly, the dataset has been adapted to the next steps by reducing strong bivariate correlations and lack of variances as presented in step 3. Fourthly, the resulting rigorous dataset has been analyzed using principal component methods to reduce dimensions of the multivariate dataset as presented in step 4. Initially, a mixed approach has been used, but MFA results have had low cumulative variances and have added multiple dimensions instead of reducing them, thus resulting in adding more complexity to the dataset. To overcome this, qualitative variables have been used as descriptive variables, and a quantitative approach has been applied using PCA. Fifthly, the resulting reduced dimensions have been used to cluster the studied cases using HCPC as presented in step 5. An interpretation of the results has unveiled characterized value chain patterns for urban factories in the urban area of Grenoble. Finally, to evaluate the coherence of the results, additional cases have been added to the dataset as presented in step 6. On one hand, each additional case has been affected to the expected cluster that best describes it, and on the other hand an HCPC has been conducted with the inclusion of the additional cases. A comparison of both affectations has been used to determine the accuracy of the clustering from the fifth step.

### 3. Case study in the Grenoble urban area: results and discussion

The application of the methodology presented in Fig. 1 has resulted in the characterization of 16 different patterns as presented in Table 1. It has been observed during the data collection process in the case study that although literature has presented urban factory as perfectly local and proximity-utilizing entities,

their implementation needs more improvement. For instance, urban factories in Grenoble have mainly focused on utilizing proximity to the local market for nearby consumption, rather than to local suppliers at the procurement level. This has been partly due to the inexistence of local materials needed for the production such as the lack of materials needed by urban factories in the textile sector which can only be found outside the Grenoble urban area. Overall, sourcing and distribution have been limited to countries in the EU. This highlights the importance of the characterization proposed in this paper which has shed light on the disparity between the fully local image presented in the literature, and the partly local image observed on the field. Additionally, additional properties should be included in the definition of urban factories such as the urban area's properties (availability of resources, demand...). Over 95% of the global variance in the used dataset has been described by the first 3 resulting principal components (PCs) defined respectively by distances to suppliers (84.2%), surfaces of the production area (9.7%), and distances to the market (5.6%). This importance of inbound logistics and outbound logistics in the definition of urban factories has also been highlighted in a previous study [3]. Additionally, most patterns from the analysis of the HCPC's results have been characterized by either small or medium surfaces for the production area. This could be explained by the limited availability of commercial space and the high rental cost in Grenoble.

Table 1: General structure of clusters' patterns interpreted over the main PCs.

Cluster	Number of individuals	Suppliers (PC1)	Surface (PC2)	Market (PC3)
1	8	Local	Small	Local
2	7	Local	Medium	Local
3	3	Local	Medium	National
4	1	Local	Small	Regional
5	6	Regional	Small	Local
6	1	Regional	Large	Local
7	4	Regional	Medium	Local
8	3	National	Small	Local
9	1	National	Small	National
10	4	EU close	Small	Local
11	1	EU close	Small	Local
12	2	EU close	Large	Local
13	1	EU close	Very large	Local
14	1	EU far	Medium	Local
15	1	EU far	Very large	EU far
16	3	EU far	Small	Local



The resulting patterns can be used to support urban factories' designers in the same urban area to identify the most successful attributes for specific variables in their value chain model. Usage for the present methodology, and the proposed preliminary version of the match-making algorithm can be extended to existing urban factories aiming to pilot benchmarking or improve their value chain dynamic. Moreover, the model can be used to extract correlations for specific value chain activities, or to validate a few hypotheses such as the acceptance of local consumers to urban factories with suppliers from far-off countries in the EU. This study has potential limitations due to the resulting singletons in a few clusters. This has been mainly a result of both forcing the model into generating an optimal number of 16 clusters, and the low availability of similar urban factories willing to share their value chain's data. The latter has been a challenging matter throughout this study due to the confidential nature of the requested data. Although, the used search protocol has been reiterated several times, many urban factories have refused to provide their data.

#### 4. Conclusions

In the present summary, a step-by-step methodology has been designed to allow the characterization of urban factories based on principle components and clustering methods as presented in Section 2. The methodology has been used to conduct a case study on 46 urban factories of the Grenoble urban area. As a result, 16 patterns of value chains have been generated using HCPC on the PCs resulting from the

previous steps. 23 additional urban factories from the same urban area have been added to the dataset to evaluate the accuracy of the clustering and validate the presented characterization.

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