Development of a method for comparing industrial processes using DSM: application to a case study in the automotive sector, the SeatBridge patent

Daniele Grazzini[1], Andrea Falegnami[1], Andrea Tomassi[1], Claudio Buccini[2], Elpidio Romano[1].

[1]International Telematic University UNINETTUNO (Rome)
[2]SB Sintec

Abstract: This study, originating from an undergraduate thesis, delves into the application of the Design Structure Matrix (DSM) to enhance efficiency in automotive processes, with a particular focus on the Seat Bridge patent case. It aims to compare traditional and innovative car seat assembly methods to evaluate and validate novel ideas, optimization attempts, and innovations. The analysis employs time and cost metrics to scrutinize the effectiveness of patents and innovative approaches. Highlighting the study is the introduction of advanced computational tools, such as the "Adjacency Matrix Exporter" plugin for Obsidian.md and a specialized Excel worksheet developed by MIT, which introduce new functionalities to support innovative processes. These tools are poised to open avenues for further research, underscoring the potential for advancements in this area. The SeatBridge case study exemplifies how innovation can be thoroughly assessed through these sophisticated methodologies, stressing the significance of ongoing exploration in this vibrant and evolving sector.

Keywords: Design Structure Matrix (DSM), Automotive processes, Time and cost metrics, Adjacency Matrix, Process optimization

1. Introduction

This research paper addresses a case study in the automotive sector aims to highlight a promising analytical approach for comparing industrial processes through the use of Design Structure Matrix (DSM) theory. During our preliminary studies, DSM emerged as an extremely intriguing and highly applicable subject. The Italian industrial landscape, characterized predominantly by small and medium-sized enterprises and informed by over a decade of field experience, could significantly benefit from a range of tools and insights to tackle management challenges, thus receiving a positive impetus. The effort behind this paper is justified by the desire to provide managers and project managers, responsible for corporate management and organization, with a profound theory that is not as well-known as it should be in Italy and in other contexts striving for excellence. DSM addresses the complexity of systems and fits perfectly into the corporate reality through the elaboration of product, process, and organizational architectures (Eppinger and Browning, 2012). It offers notable advantages, such as the use of a simple and concise visual representation of the studied situation (see Figure 1), the ability to highlight patterns in the relationship architectures among examined entities (cycles and modules), and the application of powerful mathematical analyses for optimization, including clustering and sequencing. The correspondence between graph theory (digraph representation) and matrix theory (adjacency matrix) appeared to us to be extremely interesting and very powerful for tackling the problem of modeling a process architecture through decomposition (Browning, 2001) and integration (Browning, 2002).

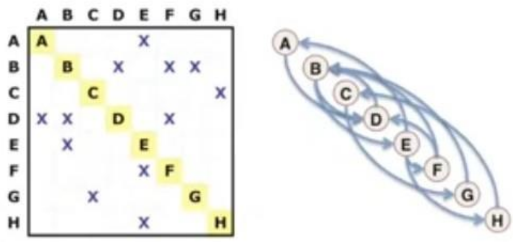


Figure 1. biunivocal correspondence between DSM matrix and digraph

Three aspects of DSM theory have guided and served as a reference for addressing our case study:

1. The application of the fundamental principles of DSM enables the construction of a comprehensive view of phenomena of interest within corporate communities that use it, fostering a spirit of collaboration and cooperation among sectors, departments, and professionals;
2. The understanding and use of the rectangular DMM matrix to map relationships across different domains. From a single DSM, multiple DMM matrices can be derived to study relationships between different domains (Danilovic and Browning, 2007), or a DSM can be obtained through the multiplication of two DMM matrices (Bonjour and Micaëlli, 2010);
3. The simulation model embedded within Excel spreadsheets with macros that derive a temporal and cost metric for a production process. The studied model, which uses discrete event simulation, was chosen because, in our opinion, it allows for greater understanding and adaptability to a generalized industrial context by characterizing the production process as a network of activities exchanging finished products (Browning and Eppinger, 2002).

In the case study we propose, unlike what is shown in the scientific literature available to us (Lee et al., 2017), where Excel spreadsheets with macros are consistently used, we utilize the software Obsidian.md, providing an innovative plugin named “Adjacency Matrix Exporter” for generating DSM matrices and simulating production times of the analyzed processes to obtain comparative parameters between the processes. The tool used for the research was represented by the Excel spreadsheets with macros from MIT in Boston, available on the institutional website www.dsmweb.org/excel-macros-for-partitioning-und-simulation. We updated and enriched them by adding the worksheet “Activities/Parameters.” This addition allows for deriving the DSM matrix as a result of processing two DMM matrices of the modeled industrial process: one for the activities/parameters of input and the other for the activities/parameters of output. After pressing the “Accept Data Below” button, the system generates the DSM matrix through an appropriate calculation algorithm that performs a sort of row-column product between the two DMM matrices. A downloadable version of this worksheet (update DSM sheets – English version.xls) and an instruction manual (Activities Parameters sheet Manual – English version.pdf) detailing the usage characteristics and explaining the steps of the implemented algorithm (those are available at the following link: https://github.com/danielegrazzini/DSM).

2. Theoretical Background

The practical problem to be solved was to validate a patent in the automotive sector. We aimed to establish a methodology for comparing, using DSM theory and a temporal metric, the traditional production process of assembling front car seats with an innovative process incorporating the SeatBridge innovation, and to provide insights on the potential benefits of this choice. For brevity and better understanding, we will refer to the "Traditional Process" as the current state-of-the-art technique implemented in the automotive industry for assembling front car seats, derived from specific industry studies and specialized information found online (technical sheets, videos, etc.). We will refer to the "Innovative Process" as the model we developed by incorporating the SeatBridge innovation into the production process simulated in our work. A fundamental starting point for our analysis was the creation of a panel of experts (engineers and managers) to make the simulation of the reference corporate context meaningful, adhering to a recommendation from the DSM theory guidelines (Dong, 2002). The data collected from the Expert Subject Matter (ESM) experts were gathered through two main techniques: focus groups (Acocella, 2015), (Caliccia, 2017), (Bezzi, 2013) and the administration of two questionnaires (Caselli, 2005) one semi-structured to collect data on the innovative process and the other structured for the traditional process. We also conducted in-person meetings simulating the internal dynamics of a company aiming to achieve the goal stated at the beginning of this work: to assign a project manager the task of evaluating two industrial processes of interest and determining which one can be chosen based on a reference parameter (in our case, a temporal metric to establish which process is faster).

3. Research design

From the meetings and data collected through the two questionnaires, we expected to obtain information useful for implementing an analysis and evaluation of the examined processes. We succeeded in gathering a series of expert opinions and observations, evaluating the patent in terms of its functionality and innovative impact[1]. This highlighted a dual methodology for the validation and comparison of two industrial processes using the Design Structure Matrix: one methodology based on Obsidian, which we called "Obsidian-based DSM Creation" (OBDC), and another methodology based on Excel spreadsheets, which we called "Excel-based DSM Development" (EBDD). In the following paragraphs, we present the two methods in their logical steps of execution and application, referencing the tools used and outlining their main characteristics. Specifically, in paragraph 4 we describe the essential features of the reference case study providing further external links to the patent and the institutional website to be able to learn more about it. In paragraphs 5 and 6 we conduct an analysis of the traditional process and the innovative process using the same development method focusing in particular on the EBDD methodology. In paragraph 7 we compare the analyzed data of each process, obtaining the characteristic time metric and identifying the fastest process. In paragraph 8 we introduce the Obsidian.md development environment and explain why we chose it to tackle our study and introduce the plugin at the basis of the OBDC methodology. In paragraph 9, we conduct a comparison of the different methods through the creation of DSM matrices for the same production process, analyzing in particular the traditional process. From this comparison we identify and highlight the differences in the results derived from using the two methods, the strengths and weaknesses of the two methods, and practical advantages and disadvantages resulting from each method. The table we propose in figure 20 summarizes the results we have reached.

4. Case Study

The founder of SINTEC, Prof. Eng. Claudio Buccini, a naval and mechanical engineer with extensive managerial experience at renowned companies, introduced SeatBridge (IT Patent link, EU Patent Link) as a revolutionary innovation in the automotive sector. The proposed solution, which elevates the seat rails through a bridge structure, not only enhances aesthetics and comfort but also promises to optimize the production process. Figure 2 illustrates the

[1] Daniele GRAZZINI, *Development of an efficiency evaluation system in automotive processes through the Design Structure Matrix: the case of the Seat Bridge patent*, Chapter 7 page 87 and Appendix A page 132. (https://github.com/danielegrazzini/DSM)

patent, highlighting its aesthetic and functional components. In the current assembly line, front car seats are assembled through two parallel lines that also include the insertion of the central console. With the SeatBridge[2] bridge structure, these components are already pre-assembled on it, resulting in a simplified assembly line.

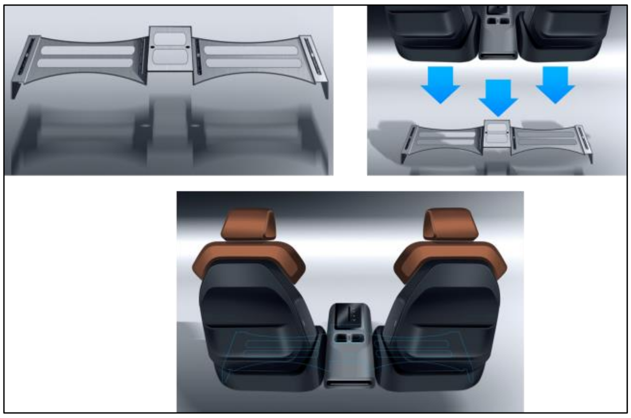


Figure 2. 3D rendering of the SeatBridge patent

5. Analysis of traditional production process using Method “Excel – based DSM Development” (EBDD)

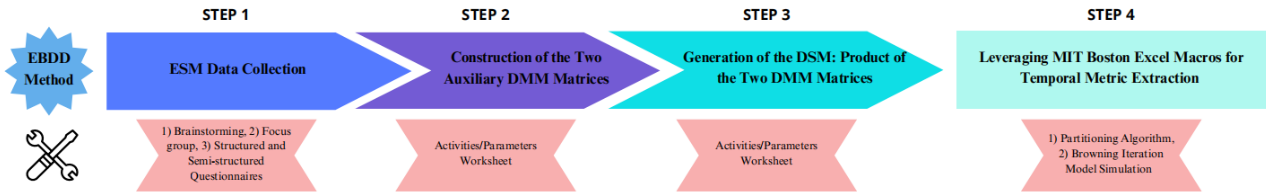


Figure 3. Phases and tools of the “Excel – based DSM Development” (EBDD) method

The starting point of the method is obtaining, through expert consultation, the main activities related to the "Traditional Process" as shown in the table in Figure 4. The proposed scheme allows for achieving several objectives: decomposing the process into a list of activities, each marked with an identifying code, and separating the expertise of the specialists into distinct areas by assigning each a precise list of activities. This outcome was made possible through the elaboration of the dataset collected from the structured questionnaire and the work done by the Expert Subject Matter (ESM) specialists, who engaged with the techniques and methods illustrated in paragraph 2.1.

LEVEL	TEAM	ACTIVITY LIST	ID
ASSEMBLY PROCESS OF FRONT CAR SEATS TRADITIONAL PROCESS (TPS)	MECHANIC	Installation of the basic structure	PT2
		Preparation of the right seat	PT3
		Preparation of the central console	PT4
		Preparation of the left seat	PT5
		Alignment and fixing of the right seat	PT6
		Alignment and fixing of the central console	PT7
		Alignment and fixing of the left seat	PT8
		Final fixing	PT9
	MATERIALS	Positioning of the shell	PT12
	SAFETY	Quality check and control	PT13
		Final verification	PT15
		Global alignment verification	PT17

Figure 4. Outline of activities in the traditional production process and corresponding identification codes

[2] Further details, explanatory videos of the patent's operation, and a comprehensive list of anticipated benefits can be found on the official website www.seatbridge.eu.

Subsequently, the ESM constructed two DMM matrices, one for input and one for output, which are shown in Figure 5 and Figure 6. The rows contain the process activities, and the columns list 10 input/output parameters: compliance check (the seats and central console are prepared and need to be verified for installation conformity to quality and safety standards); assembly, fastening points, bolts/screws (the seats are aligned and securely fixed to the chassis through fastening points using bolts and screws); visual inspection for damages/defects (after installation, a visual identification of any damages or defects is performed, and corrections are made if possible).

			Input Parameters												
			1	2	3	4	5	6	7	8	9	10	11	12	13
Activities	Element Full Name	Name Abbreviation	controllo conformità	assemblaggio	punti di fissaggio	bulloni/viti	ispezione visiva di danni/difetti	test funzionali	sistemi elettrici/meccanici dei sedili	sistemi del veicolo	verifica e regolazione	assemblaggio componenti accessori	specifiche modello auto	tipologia sedile	formazione addetti al montaggio
1	installazione struttura di base	PT2					X								X
2	preparazione sedile destro	PT3			X						X		X	X	
3	preparazione consolle centrale	PT4		X							X		X	X	
4	preparazione sedile sinistro	PT5		X	X					X	X		X		
5	allineamento e fissaggio sedile destro	PT6	X					X	X			X			
6	allineamento e fissaggio consolle centrale	PT7				X									X
7	allineamento e fissaggio sedile sinistro	PT8				X						X	X		
8	fissaggio definitivo	PT9						X							
9	posizionamento della scocca	PT12													
10	verifica e controllo qualità	PT13		X	X									X	
11	verifica finale	PT15	X												X
12	verifica allineamento globale	PT17							X						

Figure 5. Activity/Input Parameters DMM Matrix (traditional process)

			Output Parameters												
			1	2	3	4	5	6	7	8	9	10	11	12	13
Activities	Element Full Name	Name Abbreviation	controllo conformità	assemblaggio	punti di fissaggio	bulloni/viti	ispezione visiva di danni/difetti	test funzionali	sistemi elettrici/meccanici dei sedili	sistemi del veicolo	verifica e regolazione	assemblaggio componenti accessori	specifiche modello auto	tipologia sedile	formazione addetti al montaggio
1	installazione struttura di base	PT2									X				
2	preparazione sedile destro	PT3		X											
3	preparazione consolle centrale	PT4			X					X					
4	preparazione sedile sinistro	PT5												X	
5	allineamento e fissaggio sedile destro	PT6				X									
6	allineamento e fissaggio consolle centrale	PT7										X			
7	allineamento e fissaggio sedile sinistro	PT8							X						
8	fissaggio definitivo	PT9													
9	posizionamento della scocca	PT12					X								
10	verifica e controllo qualità	PT13								X			X		
11	verifica finale	PT15						X							
12	verifica allineamento globale	PT17	X												

Figure 6. Activity/Output Parameters DMM Matrix (traditional process)

After populating the matrices with relationships through a collaborative effort of comparison and reflection by the ESM, the multiplication algorithm in the Activities/Parameters worksheet was applied. By pressing the "Accept Data Below" button, the 12x12 square matrix of activities comprising the flow of the traditional process was generated, as shown in Figure 7. The discussion highlighted that the activities most involved in the complexity of interconnected cycles are precisely the phases of preparation, inspection, alignment, and fastening. It can already be affirmed that the aim of an innovation that simplifies the identified complexities is moving in the right direction.

		1	2	3	4	5	6	7	8	9	10	11	12
Installation of the basic structure	1	1								■			
Preparation of the right seat	2	■	2	■	■						■		
Preparation of the central console	3	■	■	3	■						■		
Preparation of the left seat	4	■	■	■	4						■		
Alignment and fixing of the right seat	5					5	■	■				■	■
Alignment and fixing of the central console	6					■	6						
Alignment and fixing of the left seat	7					■	■	7			■		
Final fixing	8								8			■	
Positioning of the shell	9									9			
Quality check and control	10		■	■	■						10		
Final verification	11											11	■
Global alignment verification	12							■					12

Figure 7. DSM Matrix of the traditional process using the EBDD method

6. Analysis of innovative production process using Method "Excel – based DSM Development" (EBDD)

Following the steps outlined for the traditional process, it was decided not to introduce additional activities. Instead, after receiving approval from the Consensus Panel of experts, the temporal parameters of activities were appropriately modified with the addition of the innovation. This decision aimed to minimize the possibility of comparison inconsistencies. The selection of the main activities of the process was derived from the data collected from semi-structured questionnaires, as depicted in Figure 8. The two DMM matrices shown in Figure 9 and Figure 10 were produced as preparatory steps for the formation of the DSM matrix, shown in Figure 11.

LEVEL	TEAM	ACTIVITY LIST	ID
SEATBRIDGE ASSEMBLY PROCESS, INNOVATIVE PROCESS (IPS)	MECHANIC	Installation of the basic structure	PI2
		SeatBridge preparation	PI3
		Alignment and fixing of SeatBridge	PI4
		Final fixing	PI5
	MATERIALS	Positioning of the shell	PI8
	SAFETY	Quality check and control	PI9
		Final verification	PI11
		Global alignment verification	PI13

Figure 8. List of activities for the innovative process

			Output Parameters									
			1	2	3	4	5	6	7	8	9	10
Activities	*Element Full Name*	*Name Abbreviation*	control of conformity	assembly	fastening points	bolts/screws	visual inspection of damage/defects	functional tests	electrical/mechanical system of seats	vehicle systems	verification and adjustment	assembly of accessory components
1	Installation of the basic structure	PI2									x	
2	SeatBridge preparation	PI3		x								
3	Alignment and fixing of SeatBridge	PI4			x							
4	Final fixing	PI5										
5	Positioning of the shell	PI8					x					
6	Quality check and control	PI9								x		
7	Final verification	PI11						x				
8	Global alignment verification	PI13	x									

Figure 9. Activity/Output Parameters DMM Matrix (innovative process)

			Input Parameters									
			1	2	3	4	5	6	7	8	9	10
Activities	*Element Full Name*	*Name Abbreviation*	control of conformity	assembly	fastening points	bolts/screws	visual inspection of damage/defects	functional tests	electrical/mechanical system of seats	vehicle systems	verification and adjustment	assembly of accessory components
1	Installation of the basic structure	PI2					x					
2	SeatBridge preparation	PI3								x	x	
3	Alignment and fixing of SeatBridge	PI4						x		x		
4	Final fixing	PI5						x				
5	Positioning of the shell	PI8							x			
6	Quality check and control	PI9		x		x						
7	Final verification	PI11	x			x						x
8	Global alignment verification	PI13			x							

Figure 10. Activity/Input Parameters DMM Matrix (innovative process)

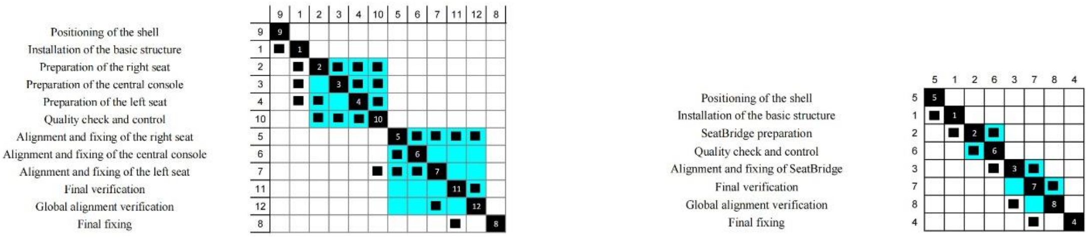
Applying the macros found in the "Activities-Parameters" worksheet, the DSM matrix of the innovative process was derived.

		1	2	3	4	5	6	7	8
Installation of the basic structure	1	1				■			
SeatBridge preparation	2	■	2				■		
Alignment and fixing of SeatBridge	3			3			■	■	
Final fixing	4				4			■	
Positioning of the shell	5					5			
Quality check and control	6		■				6		
Final verification	7							7	■
Global alignment verification	8			■					8

Figure 11. DSM Matrix of the innovative process using the EBDD method

7. Comparison of the traditional process and the innovative process studied and elaborated with the "Excel – based DSM Development" (EBDD) method: results and conclusions

After obtaining the DSM matrices shown in Figures 7 and 11, the processing of process activities was applied using the macros in the Excel sheets from MIT in Boston. Figure 12 depicts the processing of the DSM matrices through the partitioning or sequencing process for both the traditional process (Figure 12(a)) and the innovative process (Figure 12(b)).



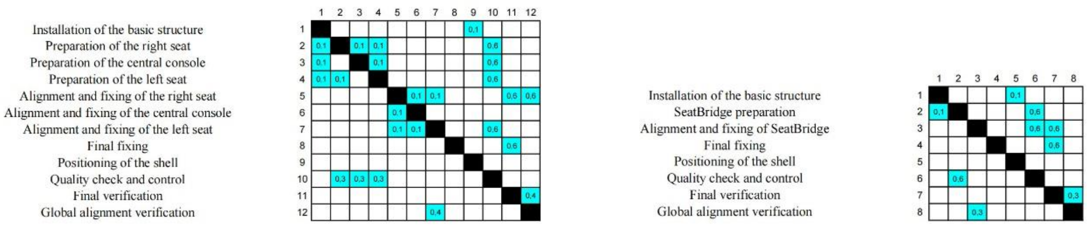
(a) (b)

Figure 12. Partitioned DSM of the traditional process (a) and the innovative process (b)

This analysis provides invaluable insights by highlighting, through color-coded activity blocks, areas where significant time losses occur, thereby pinpointing activities requiring particular attention for future process optimizations. These improvements are achieved through the tearing phase (Maheswari and Varghese, 2007), involving the selection of interdependent links to be disrupted, and through simulation of the obtained model. Simulation analysis was conducted based on a mathematical model (Browning and Eppinger, 2002) implemented within the same worksheets. This model is capable of deriving both temporal and cost parameters (with our study focusing solely on temporal parameters). The simulation model involves inputting a matrix depicting activity rework percentages, as depicted in Figure 13(a) and Figure 13(b). It also includes a matrix illustrating the impact of these reworks on subsequent activities, as shown in Figure 14(a) and Figure 14(b). Lastly, an approximate indication of timeframes for each activity is provided by constructing appropriate time interval listings, illustrated in Figure 15(a) and Figure 15(b). Data from the mathematical model are processed to generate relevant scenarios, depicted in histograms as indicated in Figure 16(a) and Figure 16(b). The number of model iterations varies case by case; for this study, the model executed 1010 simulations yielding 100 possible outcomes categorized by temporal classes on the x-axis and relative frequencies on the y-axis. Data consistency is ensured through the accuracy and reliability of converging execution batch distributions. The model maintains a precision level of α=0.01, with b=100 executions. The means (see Formula (1)) and variances (see Formula (2)) of the distributions generated by the model satisfy the following equations:

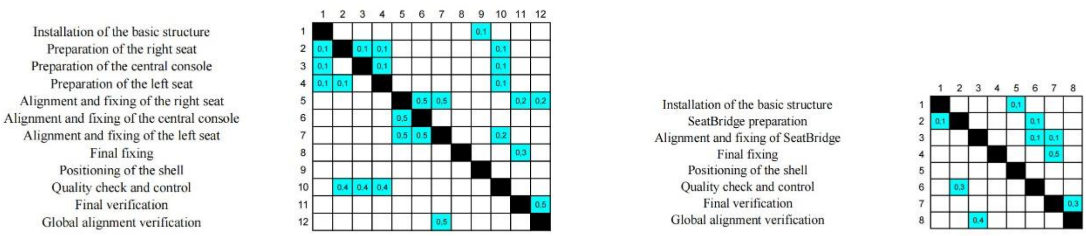
$$\frac{|E[Cr]-E[Cr-b]|}{E[Cr-b]} < \alpha \qquad (1)$$

$$\frac{\left|\sigma_{C,r}^2-\sigma_{C,r-b}^2\right|}{\sigma_{C,r-b}^2} < \alpha \qquad (2)$$



(a) (b)

Figure 13. DSM Rework Probabilities of the traditional process (a) and the innovative process (b)



(a) (b)

Figure 14. DSM Rework Impacts of the traditional process (a) and the innovative process (b)

Activities		Duration (minutes)			
ID	Name	BCV	MLV	WCV	IC
PT2	Installation of the basic structure	0,9	1,0	1,2	0,2
PT3	Preparation of the right seat	0,1	0,2	0,3	0,2
PT4	Preparation of the central console	0,1	0,2	0,4	0,2
PT5	Preparation of the left seat	0,1	0,2	0,4	0,3
PT6	Alignment and fixing of the right seat	0,5	0,8	0,9	0,3
PT7	Alignment and fixing of the central console	0,9	1,0	1,2	0,3
PT8	Alignment and fixing of the left seat	0,7	0,8	1,0	0,4
PT9	Final fixing	0,1	0,2	0,4	0,4
PT12	Positioning of the shell	0,1	0,2	0,5	0,5
PT13	Quality check and control	0,1	0,2	0,6	0,5
PT15	Final verification	0,1	0,2	0,3	0,6
PT17	Global alignment verification	0,1	0,2	0,5	0,6

(a)

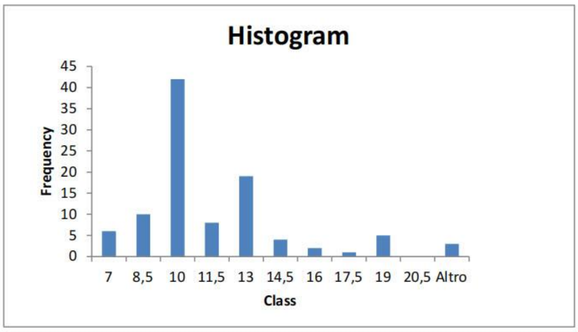
Activities		Duration (minutes)			
ID	Name	BCV	MLV	WCV	IC
PI2	Installation of the basic structure	0,9	1,0	1,2	0,2
PI3	SeatBridge preparation	0,4	0,5	0,8	0,2
PI4	Alignment and fixing of SeatBridge	1,0	1,5	2,0	0,2
PI5	Final fixing	1,0	1,2	1,4	0,3
PI8	Positioning of the shell	0,2	0,5	0,6	0,4
PI9	Quality check and control	0,1	0,4	0,6	0,4
PI11	Final verification	0,3	0,4	0,5	0,5
PI13	Global alignment verification	0,4	0,5	0,6	0,5

(b)

Figure 15. Activity diagram with indication of times for the traditional process (a) and the innovative process (b)

To determine which temporal parameter to consider, we examined four possibilities: mean, mode, median, and weighted mean of the distribution. The results are visible in Figure 16(a) and Figure 16(b). In this specific case, we observed that despite some data dispersion, the most reliable value for comparison is the mode—the temporal value most frequently chosen by the model within the time classes. Accordingly, we chose to compare the two processes using the mode parameter. The reference value for the traditional process (see Formula (3)) is therefore as follows:

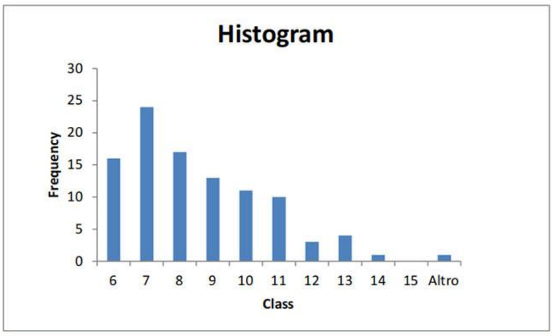
$$t_{traditional\ p.} = 10 \qquad (3)$$



TEMPORAL VALUES FOR SIMPLIFIED TRADITIONAL PROCESS

weighted mean	11
mean	14
median	14
mode	10

(a)



TEMPORAL VALUES FOR SIMPLIFIED INNOVATIVE PROCESS

weighted mean	8
mean	11
median	11
mode	6

(b)

Figure 16. Results of data processing for the traditional process (a) and the innovative process (b)

The reference value elaborated for the innovative process (see Formula (4)) is as follows:

$$t_{innovative\ p.} = 7 \qquad (4)$$

Comparing the DSM matrices of the two analyzed processes initially (see Figure 7 and Figure 11), it became evident that the introduction of SeatBridge innovation resulted in a reduction of process complexity, decreasing from 12 activities to 8. The partitioning in Figure 12(b) highlighted a simplification in the processing phases with fewer interconnections to others. Formula (5) illustrates the comparison of the temporal parameters of the two processes analyzed using the EBDD method.

$$t_{innovative\ p.} < t_{traditional\ p.} \qquad (5)$$

The innovative process yields a significant reduction in production process time, estimated at around 30%, leading to a positive assessment of improvement for the examined part. For all other aspects such as durability, acceptability, investments, weight, etc., specific industry studies are referenced to enrich the diverse evaluation data. In the continuation of this work, we aim to provide a different analytical perspective by outlining the "Obsidian – based DSM Creation" (OBDC) method. This method leverages an emerging development environment called Obsidian.md, which we believe warrants attention from the DSM community's tool developers.

8. Why choose Obsidian.md software

We have become acquainted with Obsidian.md, a software launched in 2022 by two young software engineers, and we have identified several characteristics that prompted us to delve deeper into its capabilities. The source code is open-source, and it has garnered attention from a global community of developers who are expanding its basic functionalities, making it promising for future developments. Originally conceived as a second brain to enhance an individual's ability to organize knowledge through highly organized notes, Obsidian.md is evolving to incorporate novel capabilities, such as those we observed for developing tools tailored to delve into DSM topics. In our view, this software represents a perfect embodiment of graph theory and consequently implements matrix theory powerfully and has been successfully used in many different research contexts (Tomassi et al., 2024a), (Tomassi et al., 2024b), (Falegnami et al., 2022), (Garito et al., 2023), (De Nicola et al., 2022).

8.1. The Plugin "Adjacency Matrix Exporter" and its characteristics

The Plugin "Adjacency Matrix Exporter" aligns perfectly with this direction. As its name suggests, it generates an adjacency matrix of notes within the main folder, called Vault, in Obsidian.md, which can be exported in CSV format for processing in programs like Excel. In our modeling context, if we associate each note with a process activity and linkages between notes with relationships between activities, we have the capability to study the directed graph (digraph) of the production process under study. This plugin was developed using Typescript, which is essentially a typed JavaScript, and it became available for download from the Obsidian community on December 6, 2023, following a review process by two software engineers who provided feedback and suggestions for code improvement. It features a user interface with two buttons and a clickable link. The two buttons facilitate CSV file creation in two modes: Absolute mode counts connections between notes with their multiplicity (producing a DSM matrix with weights for multiple connections or a binary matrix for unique connections). The Normalized mode divides this multiplicity by a suitable numeric parameter (producing a DSM matrix conducive to data analysis using social network analysis tools). Moreover, the link allows users to customize the CSV file separator through a user-friendly interaction box.

8.2. The Canvas feature within Obsidian.md

The Canvas feature in Obsidian.md enables the construction of a process graph in an incredibly straightforward manner, facilitating the connection of activities through graphical links. An illustration is depicted in Figure 17: the left side shows the Canvas feature's output where rectangles represent process activities and arrows connect these activities. On the right side, the program automatically generates a graph view that highlights the complexity of the relationships involved. The plugin "Adjacency Matrix Exporter" supports this functionality and can be downloaded from the Obsidian.md community at the following link: [www.obsidian.md/plugins.](http://www.obsidian.md/plugins) Simply enter "Adjacency Matrix Exporter" in the search bar to locate and install the plugin. This tool enhances the utility of Obsidian.md by allowing users to export an adjacency matrix of notes within their Vault, facilitating further analysis and visualization of process relationships.

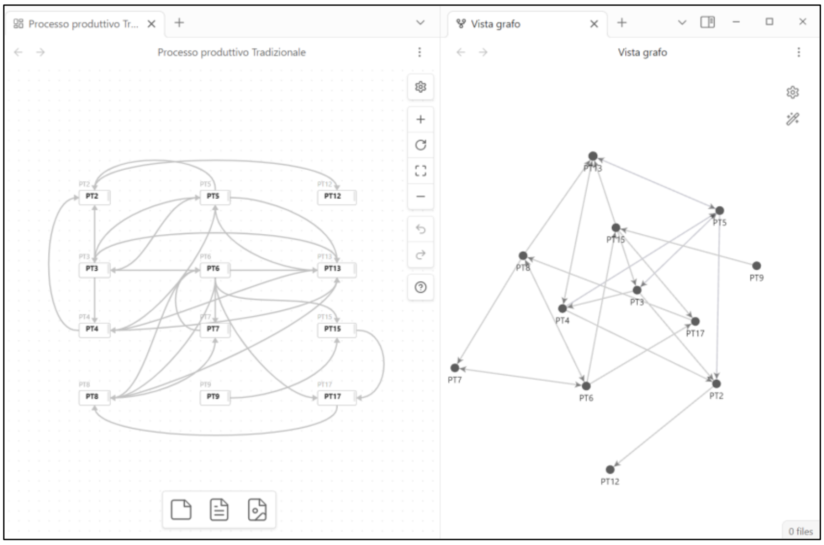


Figure 17. Diagram and graph of the traditional process within Obsidian.md

9. Comparison of different methods to create DSM matrices for the same production process

In this section, we address the comparison between the OBDC and EBDD methods with the objective of analyzing the same production process, specifically focusing on the traditional process. Below, for clarity, we outline the phases and tools of the OBDC method as depicted in Figure 18.

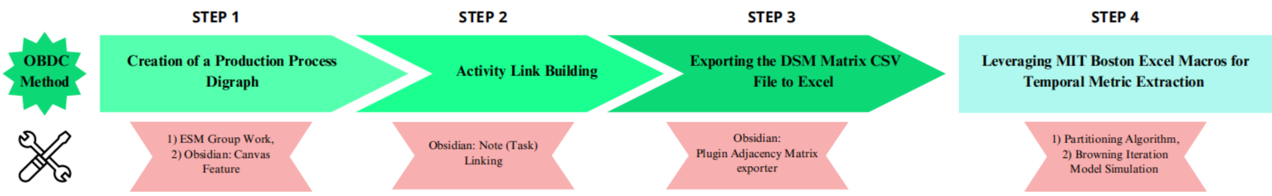


Figure 18. Phases and tools of the "Obsidian – based DSM Creation" (OBDC) method

The DSM matrices obtained using the two methods are generally different. This allows us to make some considerations and highlight peculiarities. The DSM obtained with the Excel-based method (see Figure 7) shows a greater number of relationships and different positions compared to the one obtained with the Obsidian-based method (see Figure 19).

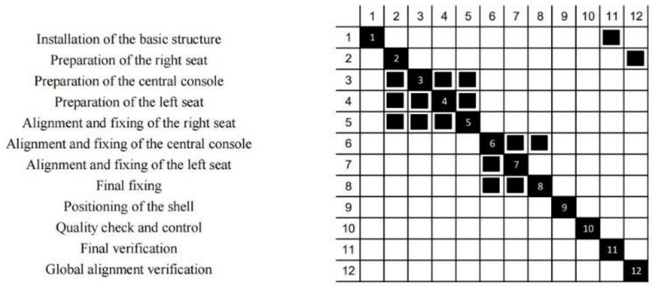


Figure 19. Design Structure Matrix (DSM) of the traditional process using OBDC method

In our view, this occurs because the EBDD method captures aspects of process complexity in a more profound manner. The OBDC methodology, based on the results obtained and the experience gained in the experimental research journey, is more suited for traditional processes or those already implemented within the company's reality and therefore "known". It can be used effectively when there are Subject Matter Experts (SMEs) familiar with the process and integrated into the company's operational environment (internal personnel). On the other hand, the EBDD methodology addresses innovative processes with greater efficacy, allowing for deeper analysis. It enables the use of external personnel as consultants, as was the case in our study. The strength of both approaches lies in their flexibility, modularity, and their ability to provide answers as new data from analyzed processes becomes available. The two methodologies proposed by this study can be applied both in forecasting, through process simulation, and in control phases, as they can adapt and update as new data is collected. Generally, since comparing average process times might not yield reliable results if the values are very close to each other, we plan to address this issue in the future by focusing on confidence intervals and incorporating statistical research to support the examined methods.

	Easy of use	**Tools used**	**Number of phases**	**Characteristics of the produced DSM**	**Strengths**	**Weaknesses**
OBDC Method	Medium/High	Obsidian, Plugin Adjacency Matrix Exporter, Canvas feature, MIT Excel Macros	4	Low number of relationships	Study of traditional processes, use of Subject Matter Experts (SMEs) in the examined production process	Innovative processes, highly impactful expert perspectives
EBDD Method	High	Activities/Parameters worksheet, MIT Excel Macros	4	High number of relationships	Study of innovative processes, depth of analysis, use of external consultants, flexibility, modularity	Traditional processes, potential distance of experts from the analyzed production sector

Figure 20. Comparative table of the two analyzed methods: OBDC and EBDD

10. Conclusions and future developments

In this work, we have presented a dual method for comparing the efficiency of industrial processes using Design Structure Matrix (DSM) and applied it to the case study of the SeatBridge patent in the automotive sector. The goal was to evaluate innovation compared to the traditional process in terms of time (cost analysis was not addressed in this study). The analysis results demonstrate that the innovative process with the SeatBridge patent offers significant time savings compared to the traditional process. This outcome indicates that the innovation has the potential to enhance the efficiency of the production process in the automotive sector. However, this study has several limitations that should be considered. Firstly, it is based on a single case study, which limits the generalizability of the findings. Secondly, the data used for analysis were collected from a panel of experts not directly from the automotive sector, potentially affecting data quality due to their knowledge and experiences. Finally, the methods proposed and developed in this study have not yet been validated by other research. The two approaches we described, EBDD and OBDC methods (analyzed in Table of Figure 20), can be used to compare the efficiency of two processes and identify areas for improvement. It's important to highlight that by obtaining two DSM matrices for the same production process, we have the opportunity to use both methods to deepen our understanding of the process itself and potentially derive a DSM that serves as a compromise between the first and second matrices. The bespoke computational tools we developed are envisioned to pave the way for future research in this field. Specifically, we aimed to highlight the potential of the DMM matrix (Browning, 2016) as a highly effective tool for analyzing innovative processes. We are already exploring aspects that we intend to investigate further in the future, which we believe will suggest additional enhancements. Obsidian, for instance, already includes plugins that incorporate ChatGPT among the tools available to developers, making it a promising software environment for future tool enrichments in favor of DSM. The methods examined need to be expanded to enable comparison across multiple scenarios, not just two, and incorporate additional statistical tools that we believe will enhance the current impact of this work.

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Contact: Daniele Grazzini, International Telematic University UNINETTUNO, Management Engineering, Rome, Italy, d.grazzini@students.uninettunouniversity.net, danielegrazzini@libero.it