USING ENTERPRISE ARCHITECTURE ANALYTICS TO IMPROVE ORDER MANAGEMENT, A CASE STUDY

Bachelor Thesis in Industrial Engineering and Management
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Management Summary

As follows the reader is presented a description of the problem tackled by this research, the methodologies used for this purpose, the results, and the conclusions. This material is presented briefly, for a detailed account of the matter, the reader is referenced to the respective paragraphs of the paper.

Problem Definition

F.I.V. E. Bianchi S.P.A. is a bike producer who recently started offering customizable bicycles. However, the rising demand for this product and the suboptimal internal processes are causing the firm to experience unusual operational distress. In particular, the production manager feels that the planning department is exceptionally overloaded, thus, I was appointed to cooperate with him to solve the matter.

To begin with, the issue was analysed to derive its fundamental causes and among them, the slow data handling process of customizable bikes was agreed to be the most relevant. The problem was quantified by analysing the budget allocated to the process and its actual execution cost, their difference generates the gap between norm and reality. In practice, over the last year, the planning department spent on average 15,5 hours a week to enact the data handling process of customizable bikes, whereas this value ought to be 9 hours according to accounting decisions. Among the causes of this matter, the inadequate configuration of the enterprise resource planning system was deemed as the most relevant.

Methodology

Thus, the knowledge problem was formulated as “How can Bianchi reconfigure the enterprise resource planning system to speed up the data handling process of customizable bicycles?”. To tackle the issue, the grand framework of Design Science Research Methodology was used. Moreover, its steps were integrated with those of three topic-specific methods. Firstly, the Managerial Problem-Solving Methodology enabled to identify the core problem from the interdisciplinary viewpoint of business administration. Then, the Hierarchy of Research Questions supports the development of a scientific research designs and finally, Business Analysis Body of Knowledge allows to approach the solution generation from the perspective of business process analytics.

The methodology is composed of four main steps. Firstly, the current state of the process was mapped and analysed by means of interviews and observations. Then, target architectures were designed for the workflow application layer, and their consequences on the business process were portrayed. The development was based on the need for performance, cost efficiency, modifiability, and resilience. The problem owner was involved in the solution selection within the procedure of analytical hierarchy process, and given the most desirable result, an implementation plan was devised based on the agile development methodology.

Results

First, performance, implementation cost, ease of modifiability and resilience were determined to be the four most relevant design objectives. Then, the baseline data handling process of customizable bicycles was mapped by means of ArchiMate. Of its activities, three were supported by the enterprise resource planning system, namely “Update manufacturing and distribution orders”, “Update excel” and “Transport Tasks”. Their respective completion time were reported to be between 162 and 183, 83 and 104, 125 and 176 seconds per bike. Moreover, their attributes were computed, and it appears that, while resilience was to increase only for the third process, the cost and modifiability were to be

enhanced for the entire system. Then, given the core problem, performance was to be upgraded for all the workflows.

Afterwards, the strategy to innovate "Update manufacturing and distribution orders" concerned automating the production planner tasks into the enterprise resource planning system scripting tool. The "Update excel" process was improved by programming the excel overview into the enterprise resource planning system mashup and automating its iterative update. Finally, the strategy to ameliorate "Transport Tasks" was based on the idea of outsourcing activities to external software. Again, the resulting target architectures were measured. Cost was generally better, and modifiability was improved. As of performance, these workflows will achieve the research goal if duration decreases by at least by 0,32% every 1% growth in their automation level. In light of this analysis, the implementation order was "Update manufacturing and distribution orders", "Update excel", and "Transport tasks".

However, after applying analytical hierarchy process to know the opinion of the decision maker, it resulted that "Update manufacturing and distribution orders" was the most urgent workflow to implement, closely followed by "Transport Tasks", and "Update excel" was last. Yet, modifiability is expected to grow in importance and cost to decrease. Hence, this scenario was investigated by means of a sensitivity analysis. Here, it was discovered that if the importance of cost varied by x units and that of modifiability by y, "Update manufacturing and distribution orders" remains optimal only as long as $y > -0{,}63 - 1{,}66x$. Moreover, within a variation of 100% and 200% in cost and modifiability relevance, "Update excel" is never the preferred option.

For this reason, the implementation stage was performed on "Update manufacturing and distribution orders". The realization was split into three steps according to the Agile Development Methodology. First, the insertion of manufacturing and distribution orders should have been executed on the forecast visualizer screen. Then, the ability to gain an empty forecast slot autonomously should have been coded in the tool, and finally, the logic should have been customized to trigger automatically when a new customer order arrives.

Conclusion

To conclude, the implementation of the processes will attain the 43% duration reductio only if this variable drops by at least 0,32% every 1% increase in process automation level. In this case, the research problem will be solved. As of further research opportunities. Firstly, the target architecture of "Transport Tasks" entails scheduling the logistical operations. The development of models suitable for the given problem is left for further research. Also, refining "Update manufacturing and distribution orders" implementation strategy is another opportunity because the current one aims to be feasible rather than optimal. In addition, another research possibility is designing an implementation strategy for "Transport Tasks", and for "Update Excel".

Foreword

Dear Reader,

In this paper you will find my bachelor thesis. The paper starts with a thorough analysis of the problem context, and it then translates the practical issue into the knowledge which is needed to solve it. I researched all this information and eventually, I was able to capitalize on my fantasy and draft some solutions to the matter. This paper has a marked IT nature, and it deals with ERP customization mainly. The solutions were generated in a bottom-up fashion. Meaning that I spent much time studying in detail what could and what could not be done with the ERP program. On the one side, this ensures the feasibility of the results, on the other side, this fetters their universality.

Before you go on reading, I want to thank Mauro for all the time he spent looking after me, despite his hectic schedule. I want to thank Lisa, Michele, Alessandro, and Samuele; they are the production planners who spent ages explaining me the current process and how to use the ERP system.

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Glossary

Notation	Meaning
aECP	Aggregated Event Driven Process Chain
AHP	Analytical Hierarchy Process
API	Application Program Interface
BPM	Business process modelling
BPM4KI	the Business Process Meta-model for Knowledge Identification
BPMM	Business Process Management Methodology
BPMN 2.0	Business Process Modelling Notation version 2.0

BtoB	Business To Business
CB	Customizable Bicycle
C-ECP	Configurable Event Driven Process Chain
CO	Customer order
CS	Process Implementation Cost
DCP	The Data-handling of Customizable-bicycles Production
DO	Distribution order
DSRM	Design Science Research Methodology
EA	Enterprise Architecture
EBSCO	Business Source Elite
EDCP	DCP activities which take place in or interact with the ERP system
eECP	Extended Event Driven Process Chain
EPC	Event Driven Process Chain
ERP	Enterprise Resource Planning system
FAML	Functional Actor Modelling Language
GSPN	Generalized Stochastic Petri Nets
IDEF	Integration DRFinition set of modelling languages and practices
IQ	Investigative Question
IT	Information Technology
KMDL 2.2	Knowledge Modelling and Description Language version 2.2
KP	Knowledge Problem
MD	Workflow Modifiability
MO	Manufacturing order
MPSM	Managerial Problem-Solving Methodology
MRQH	Managerial Research Question Hierarchy
MVP	Minimum Viable Product
MVRP	Multi-Vehicle Routing Problem
Oliveira	Oliveira's Methodology for modelling knowledge sensitive processes
PF	Process Performance
PROMOTE	Process-Oriented Methods and Tools for Knowledge Management
RAD	Role Activity Diagram
RE	Architecture Resilience
RQ	Research Question
SAN	Stochastic Automata Network
S-BPM	Subject Oriented Business Process Modelling
SoaML	Service Oriented Modelling Language
SoftPM	Software Process Modelling Language
SPA	Stochastic Process Algebra
UML - AD	Unified Modelling Language version 2.0 Activity Diagram
YAWL	Yet Another Workflow Language

Table 1 Glossary

1. Introduction

E. Bianchi is a globally operating bike producer based in Milan. The company produces racing, mountain, and city bicycles for various price segments of the market, and in recent years the organization has enjoyed a thriving growth. However, as it often happens with rapid flourishment, the expansion of operational capabilities could not fully couple the increase in market share and, as a result, several departments present symptoms of distress. The board of management is already working in cooperation with functional staff to envisage solutions, and in this context, I was offered the chance to cooperate with the production planning unit as a consultant. I am tasked to analyse the situation and suggest methods to subside operational clog.

As of this section instead, chapter 1.1 introduces the reader to the firm's processes which are relevant to this study, while part 1.2 elaborates on the theoretical methodology which guides the research. The next section dives into the matter by identifying and choosing a relevant problem in the organization. Since its solution is unknown, it is treated as a knowledge problem and section 1.4 derives research questions and designs to solve it. Subsequently, chapter 2 tackles the inquiries which called for literature research. On a more practical level, section 3 identifies theoretical requirements and turns them into practical criteria on which to base the solution development. Then, part 4 analyses the current state of the process both in its business and application levels. As this step closes, architectural and processual improvements are designed in section 5, scored in section 6, implemented in passage 7, and commented upon in the eight. This last instance works as a conclusion too.

1.1 Hosting Organization

In their facility, E. Bianchi assemblies two broad families of bikes which differ largely in their production and scheduling processes. Namely, customizable bicycles are fashioned in a pull system triggered by market demand, whereas standard ones are manufactured in a push scheme anticipating consumer requests (Chopra & Meindl, 2007, p. 64). As of the former, figure 1 introduces Bianchi's pull dynamics with a focus on communication among inter and intra enterprise actors. This ArchiMate actor co-operation process with its subject-orientated view will enable the reader to grasp the processes without bogging down in details. As of the modelling language, the reader is referenced to The Open Group (2021) for a description of its elements meaning.

Unlike traditional bicycles, the production of custom bikes initiates only upon demand arrival. The whole process starts with the commercial department receiving orders and monetary transactions from the distributors, who are in contact with the final consumers. These requests for custom bicycles are periodically shared with the planning department who must carry out four main tasks. First, it must vary the production plan by fitting a batch of customizable goods within the standard ones. Once settled, the replacement must be communicated to the commercial department which retcons the firm's monthly financial position. Then, given the bike production date, the supply chain function establishes when the delivery will occur, and this notion is transmitted to retailers together with billing information. But before the assembly can happen, the planning department must tailor the single components onto client specifications. Since a part of the painting process is outsourced, this division must also coordinate the interaction with its colouring suppliers.

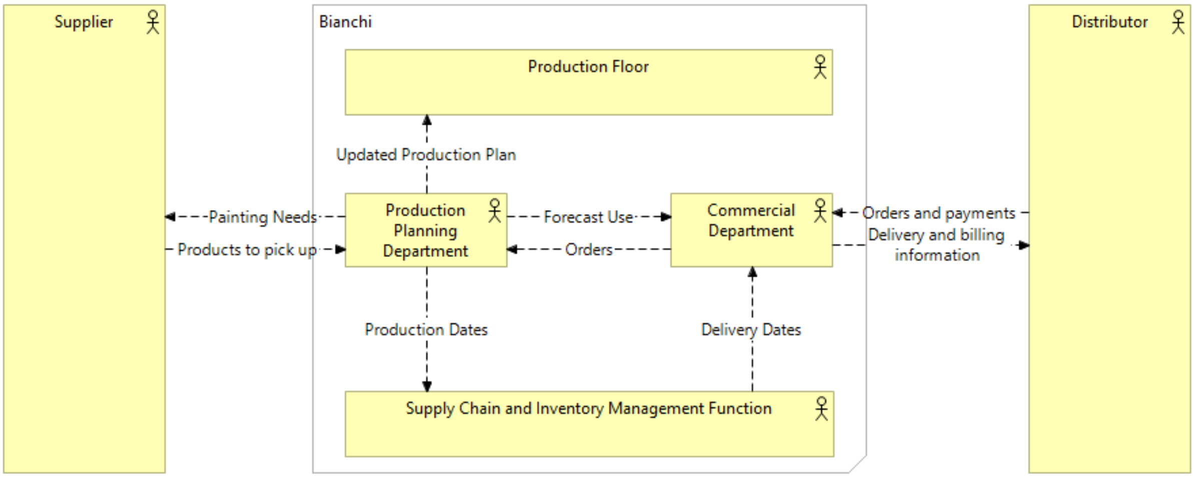

Figure 1 Actor Co-Operation view of the customizable bikes processes

Overall, four company branches are involved in the processes relevant to this paper. Firstly, the supply chain and inventory management operatives work to order material, monitor stock levels, and organize goods transportation. Next to it, the production planning department concentrates on scheduling manufacturing operations, and coordinating their quotidian execution. Finally, the commercial function is responsible for intaking and processing the financial dimension of orders, whereas the factory floor is restricted to the practical assembly of bikes. Note that, despite most communications are based on IT infrastructures, the IT department is not depicted in figure 1 because its role adds no direct value to the product generation.

1.2 Theoretical Framework

To devise how to assuage operational distress, this research relies on the grand framework of Design Science Research Methodology (DSRM) as outlined in figure 2 (Peffers et al., 2007). This methodology draws on scientific knowledge to achieve established goals by means of technological artefacts. Out of its six steps, I perform the first four passages and, I integrate its methods with those of the Managerial Problem-Solving Methodology (MPSM), Business Analysis Body of Knowledge (BABOK), and Management Research Question Hierarchy (MRQH) (Heerkens & Van Winden, 2021, p.12; Jonasson, 2016, p. 159; Cooper & Shindler, 2006, p. 108).

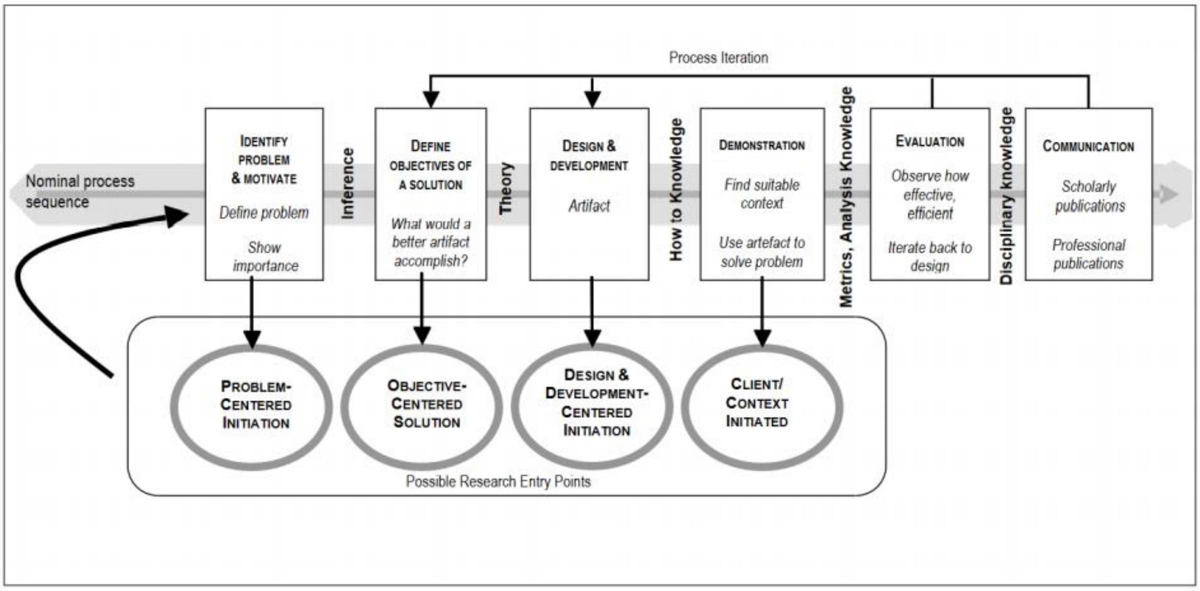

Figure 2 Design Science Research Methodology procedure map (Peffers et al., 2007)

The need for these integrations stems from DSRM high level of abstraction. In fact, its directives are broad enough to guide various projects in the IT environment and they do not have specific execution blueprints. Therefore, a more detailed and field-specific procedure was created by merging it with the other three methodologies. At first, MPSM allows to investigate the core problem from various theoretical perspectives thanks to the multidisciplinary of its business administration approach. Also, it capitalizes on psychological tenets for the generation, selection, and implementation of solutions. In addition, MRQH enables to identify the core problem and draft the research design in a rigorously scientific manner. Finally, BABOK drafts guidelines for a quantitative examination of firm's business processes and architectures, which is the perspective adopted for the solution generation phase. Therefore, although these frameworks include similar research activities, their methods differ, and they are to be integrated to enact DSRM at its best.

Moreover, table 2 outlines which methodology will integrate each DSRM phase. In practice, "Identify Problem and Motivate" is tackled by clustering the problem environment and analysing the core problem as explained by MPSM phase 1 and 2 (Heerkens & Van Winden, 2021, p.23). Moreover, a similar logic is presented in the first two steps of the MRQH which is thus complementary (Cooper & Shindler, 2006, p. 108). In regard of "Define Objectives of a Solution", the criteria selection is performed as explained in MPSM phase 5, whereas the resulting design guidelines are translated into practical requirements as prescribed by the "Requirement Analysis" phase of BABOK (Heerkens & Van Winden, 2021, p. 98; Hailes, 2014, p. 57). Then, the "Design & Development" stage starts by mapping the current business process and application stack to assess its capabilities as prescribed by BABOK "Assess Capability Gap" phase (Hailes, 2014, p. 33). Subsequently, this knowledge is used to complete MPSM phase 5, generate solutions and score the best of them by means of Analytical Hierarchy Process (AHP). Finally, the "Demonstration" step convolutes MPSM stage 6 with the remaining of BABOK "Requirement Analysis" to define a social and technical change strategy.

DSRM Phase	Integration	Description
Identify Problem and Motivate	MPSM	Phase 1 and 2: problem clustering and analysis
	MRQH	The hierarchy of research questions
Define Objectives of a Solution	MPSM	Phase 5: Solution Generation
	BABOK	Requirements Analysis
Design and Development	MPSM	Phase 5: Solution Selection
	BABOK	Assess Capability Gap
Demonstration	MPSM	Phase 6: Solution Implementation
	BABOK	Requirements Analysis

Table 2 Integration of DSRM with MPSM, MRQH, and BABOK

1.3 Identify Problem and Motivate

As the first step of the DSRM prescribes, the project is started researching the root cause of the given issue and outlining its importance. This passage is tackled in two phases using the knowledge of MPSM. First, the problem identification is carried out (Heerkens & Van Winden, 2021, p. 39). Then, the most important cause is analysed to find its deeper triggers (Heerkens & Van Winden, 2021, p. 61) For the rest of the paper, the fundamental matter causing managerial concern is referred as Core Problem (Heerkens & Van Winden, 2021, p. 43) and Managerial Dilemma (Cooper & Shindler, 2006, p. 108) interchangeably.

1.3.1 Problem Context

Within the planning department, the production manager has the impression that his team is overloaded with labour. This managerial concern rose because of two apparent symptoms. In fact, he knows that most employees work long hours overtime, and he realizes that some feel worn out. In accordance with MPSM terminology, he is the problem owner insofar as he is responsible for generating a solution to the matter (Heerkens & Van Winden, 2021, p. 22). Moreover, in his perception, the undue amount of work on the production division of the planning function is the issue to be solved.

Considering this condition as the consequence of a deeper subject, the problem identification phase was initiated. Primarily, the production planners, were surveyed to log the problems which they perceived. This list was subsequently polished, and it can be found in appendix A.1. Based on this directory, the space of relevant problems was ordered in the "Problem Cluster" box of figure 3, neglecting the issues which could not be influenced.

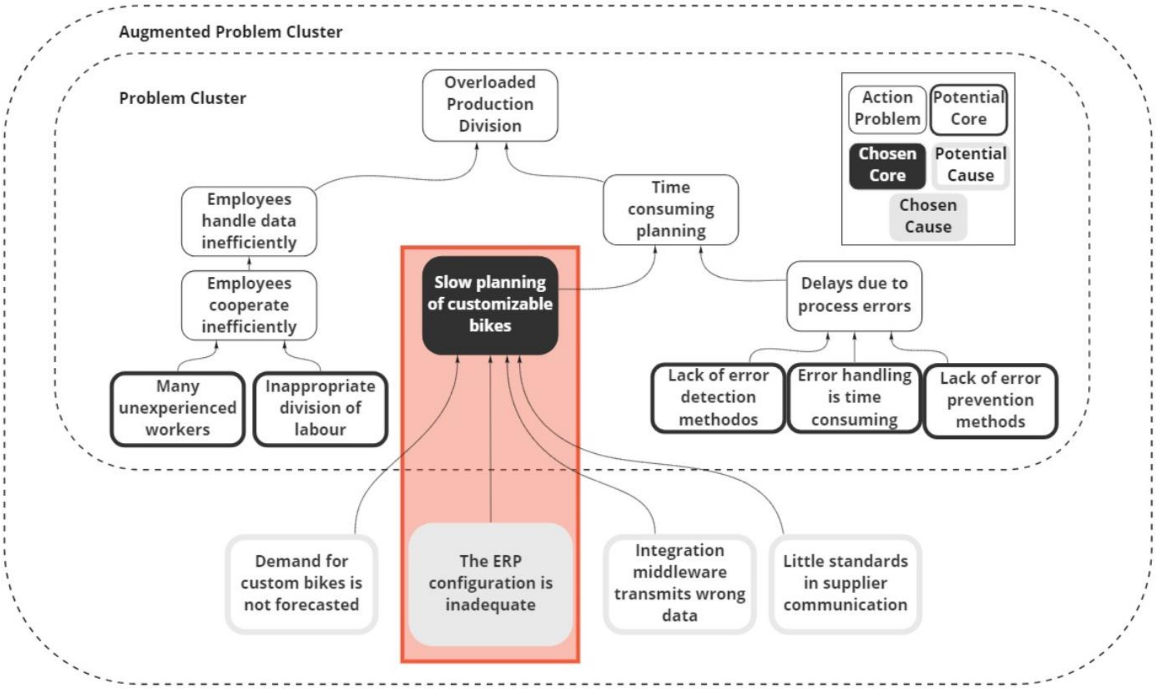

Figure 3 Problem cluster and problem analysis

At the top of the pyramid, the overload of the planning division stands as the given action problem (Heerkens & Van Winden, 2021, p. 21). It appears that this issue is directly caused by two main elements. On the left, the fact that employees are slow at handling data is considered. This appears to be due to an inefficient interaction among operators from various functions, which is caused by the abundance of inexperienced workers and the fact that the same activity is taken over by various departments, generating intense exchange of information. On the other hand, production planning activities are excessively time consuming. Among these, the operations of configurable bikes are considerably time expensive. Quoting the production manager, "the data handling process of customizable bicycles production" (DCP) "feels disproportionally bigger than that of other products, and this is even increasing". At the same time, nonoperating time is believed to be significant because of process errors occurring inside the department, within juxtaposed business functions and in relation to firm suppliers. These mistakes are enabled by partiality of error prevention and detection methods within the firm divisions. Plus, they are often rather expensive to fix. For instance, they might compromise the production of bicycles batches or track wrong inventory levels, both of which require thorough analysis of given orders to identify the mistake and patch it.

After a consultation with the problem owner, the slow DCP was agreed to be the most important problem because of its perceived impact onto the overload level of the production division. In fact, the problem owner believes that the intrinsic length of planning operations exacerbates the operational clog more than the inefficient cooperation among employees. This idea is motivated because, although workers can make up for their wasteful interactions by working faster, they cannot shorten the process itself for they lack the overall knowledge of it. At the same time, the extensive DCP appears to impact the workload more than the process errors. The logic supporting this assertion is like that at the basis of the latter because process errors impact workflow execution speed. However, employees are up to compensating for delays with extra commitment and swiftness. On the contrary, little they can do to shorten the DCP process. For all these motives, it is patent that the remaining matters are relevant. However, to solve the drawn-out DCP is more urgent, and it would yield greater benefits.

1.3.2 Operationalization

Many indicators exist in literature to measure the efficiency of a business process (Annett & Stanton, 2000, p.12), but in line with Heerkens & Van Winden (2021, p. 49), only one is used here. After a brief exploration, the mean throughput time appeared to be the most direct scale on which to calculate this factor and it is here defined as the total completion time of the DCP (Slack et al., 2010, p. 64) – note that this term is used interchangeably with cycle time in this paper. Then, to make pricing decisions, the commercial department allocated a specific budget to the data handling process of customizable bicycles. If operator working time is the only process cost, and overhead expenditures are neglected, it can be inferred that the commercial department requires the DCP of a single bike not to take more than 4 minutes. However, preliminary interviews with the planning operators bear out that this value is currently distributed around 7 minutes rather than 4. In other words, since the function had to process a mean of 132 custom bikes a month last year, the planning department spent roughly 15 hours and a half a week enacting the DCP, whereas this value ought to be about 9 hours. Hence, the Managerial Dilemma is given in table 3:

<table>
<tr><th>Variable</th><th>Norm</th><th>Reality</th><th>Problem Owner</th></tr>
<tr><td>DCP weekly time-expense</td><td>9 hours a week</td><td>15,5 hours a week</td><td>Production Manager</td></tr>
<tr><th colspan="4">Action Problem</th></tr>
<tr><td colspan="4">Over the last year, the planning department of E. Bianchi spent on average 15,5 hours a week to enact the DCP, whereas this value ought to be 9 hours.</td></tr>
</table>

Table 3 Action Problem

1.3.3 Problem Analysis

Before taking a closer look at the core problem, as Heerkens & Van Winden (2021, p. 56) suggest, information about stakeholders was gathered and summarized. Next to the problem owner, four production planners, three warehousemen, and the sales accountant, are Bianchi's problem victims because they are affected by the core issue without being capable of solving it themselves, within figure 1, they are located respectively in the "Production Planning Department", the "Inventory Management Function" and in the "Commercial Department". Together with the IT, production, and commercial managers, the planners and the sales accountant are also problem helpers – those who can aid in the solution development. Note that, albeit victims, the warehousemen are not deemed helpers. In fact, since they act upon planners' orders, the planning operators have a better understanding of warehouse DCP processes than them. The organigram in appendix A.2 gives a structured overview of these stakeholders.

Following this brief overview, the problem analysis phase aspires at locating causes for the slow DCP, and since no motive had been uttered by the workers in the problem identification stage, a combined approach was adopted. As suggested by Heerkens & Van Winden (2021, p. 63), a literature search was performed to identify factors effecting the core problem in similar companies. For clarity purposes, its results and search strategy are reported in appendix A.3. Then, the IT, production and commercial managers were interviewed to establish which of the search findings applied in this case. Eventually, the discussion shed light on four issues effecting the managerial dilemma in Bianchi, and the problem cluster of figure 3 was augmented to incorporate them. In fact, the lack of a dedicated forecast for customizable bikes makes the process longer as it needs to rely on the aggregated prognosis. Also, queries happen to extract data in the wrong format and correction procedures are based on human labour. Thirdly, protocols for supplier coordination are unstandardized and the enterprise resource planning system (ERP) configuration is inappropriate to serve the DCP.

This improper design causes two major hindrances to process performance according to the IT manager. Firstly, when the ERP translates orders of custom bikes into manufacturing jobs, it does not transmit the aesthetical specifications. Therefore, production information for these units must be updated manually. In addition, ERP order tables do not have all the fields needed to track the production processes of configurable goods. Hence, these passages are followed on auxiliary software, waning the operative speed. Considering this evidence and after a discussion with the problem owner, the inapt configuration of the ERP is chosen as the major contributor to the core problem.

1.4 Research Design

As the first phase of DSRM ends, the following aims at systematizing the research needed to tackle the fundamental problem by varying the Enterprise Resource Planning System. At first, the knowledge problem is formulated. Then, research questions are derived, and their study design is uttered. Eventually, deliverables are delineated in respect of each research question.

1.4.1 Knowledge Problem

Therefore, the scope of this research is skirted on the interaction between the ERP configuration and the DCP completion time. This connection is shaded in red in figure 3 and it is conceptualized in the theoretical model of figure 4, while its variables meanings are given in table 4. Although the company itself is the research population, the specific subjects are outlined for each sub-question in the following. Accordingly, the fundamental Managerial Question, or Knowledge Problem (KP) (Cooper & Shindler, 2006, p. 108; Heerkens & Van Winden, 2021, p. 121) becomes:

"How can Bianchi change the ERP configuration to reduce the DCP throughput time by 43%?"

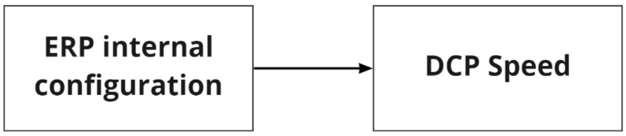

Figure 4 Knowledge problem

Variable	Definition
ERP configuration	Handling of usage controls to shape the databases functionalities and operational workflow, as suggested by Clemmons and Simon (2001)
DCP speed	Number of orders completing the DCP in the time unit, also called throughput rate. (Slack et al., 2010, p. 65)

Table 4 Variables of the core problem

And the consequent research goal (Heerkens and Van Winden, 2021, p. 119) is:

“Devise improvements to the ERP configuration in order to speed the data handling of custom bikes, and design how to implement the enhancement in practice”

1.4.2 Research Questions

Since DRSM aims to devise an artefact that tackles the identified problem, to answer the managerial question is to find the information for DSRM phase 2, 3 and 4. Subsequently, the study goal can be achieved by enacting DRSM on the basis of the gathered knowledge. The research questions (RQ) outlined hereafter are threefold and they cover most of the knowledge needed to vary Bianchi’s ERP and tackle the issue. Also, some sub-questions are derived toward the creation of Investigative Questions (IQ) (Cooper & Schindler, 2006, p. 113). While table 5 lists them according to the chronological order in which they will be solved, table 6 outlines their data gathering method and table 7 the respective deliverables.

Firstly, RQ 1 is meant to preliminarily investigate what languages can describe the collaboration between workflows and information systems. Subsequently, RQ 2 illustrates how to perform the “Define Objectives of a Solution” phase of DSRM. In fact, in line with Heerkens and Van Winden (2021, p. 77), the researcher prevents decisional bias by identifying solution characteristics early on. Then, as mentioned in section 1.2, the “Design and Development” step is carried out by means of BABOK gap analysis. Therefore, RQ 3 identifies the DCP landscape, and maps the EDCP, then RQ 4 investigates the process completion time to carry out the capability assessment of the BABOK methodology. After that, RQ 5 investigates how the ERP architecture can be varied to shorten the EDCP and RQ 6 selects the most desirable reengineered configuration to conclude DSRM phase 3. In the end, the “Demonstration” stage is performed by answering RQ 7, which enquires about the optimal solution social and technical implementation.

What languages can be used to model the human and digital workflow of the order management on an operational level of abstraction?	RQ 1
What attributes are desirable for a novel ERP configuration in the context of the slow DCP?	RQ 2
What are relevant criteria for the assessment of a configuration performance?	RQ 2.1
What is the relevance of these characteristics?	RQ 2.2
What is the current DCP workflow and how does the IT system support it?	RQ 3
What is the DCP landscape, with its data dependencies and relevant data structure?	RQ 3.1
What is the EDCP business workflow and how does the application stack support it?	RQ 3.2
What are the major bottlenecks among the EDCP activities?	RQ 4
What is the completion time of the EDCP activities?	RQ 4.1
How should the ERP be reconfigured to attain the solution objectives and reduce duration?	RQ 5
How can the ERP be varied with respect to each EDCP task to redesign architectures with improved attributes and lower duration?	RQ 5.1
What is the priority in which redesigned architectures should be implemented?	RQ 6

What is the desirability of the reengineered processes?	RQ 6.1
How can the most desirable reengineered process be implemented?	RQ 7
What technical steps are to be carried out to implement the most desirable process?	RQ 7.1

Table 5 Outline of Research Questions

Before describing the way in which the research questions are to be answered, it is important to outline where the reader can find their reply. In fact, RQ 1 is elaborated in section 2. Then, in section 3 the solution objectives are identified and operationalized. Section 4 answers RQ 3, and 4 respectively. Despite being treated simultaneously; these inquiries must be separated because of their dissimilar research designs. Next, RQ 5 is tackled in section 5, while the subsequent section establishes which redesigned architecture the problem owner prefers. In conclusion, section 7 answers research question 7, and section 8 gives the conclusions of the paper.

1.4.3 Research Design

Given the plenitude of research questions outlined so far, this passage aims to structurally describe their research design. Firstly, for each RQ, a broad overview of its data gathering, and analysis methods is given in table 7. Here, the "Research Structure" column has research type, depth, and population as entries. Under "Data Gathering Methods", study type, subjects, and time span are outlined whereas the last columns show the study data output and its analysis methods. Moreover, in appendix B their concepts are defined in table 25 and their operationalizations are illustrated in table 26.

Research Question	Research Structure	Data Gathering Method	Data analysis Method
1	Descriptive and qualitative; broad; on online literature	Literature review on scientific articles (Cross Sectional)	Qualitative synthesis and cluster of languages according to their characteristics
2	Descriptive, qualitative and quantitative; deep; on production manager	Depth interview on production manager (Cross-Sectional)	Qualitative list of relevant criteria and quantitative measure of their importance
3	Descriptive and qualitative; broad; on the DCP	Expert interview on planners, commercial, production, IT manager and sales accountant (Cross Sectional)	Qualitative visual representation of process flow and its layers' interaction
4	Descriptive, quantitative; deep; on EDCP activities	Expert interview on planners (Cross Sectional)	Tabulation of completion time and comparation to rank activities accordingly
5	Descriptive, quantitative, and qualitative; broad and deep; on ERP structure and business process	Case Study on planners, IT manager, sales accountant, ERP testing environment, manuals, and literature (Cross Sectional)	Qualitative technical representation of reengineered process models with scores of their solution objectives

6	Descriptive, quantitative; deep; on Production Manager	Deep Interview on production manager (Cross Sectional)	Quantitative measurement of desirability of each solution, with sensitivity analysis on optimality
7	Descriptive and qualitative; deep; on ERP structure	Case Study on IT manager, ERP manuals, testing environment (Cross Sectional)	Qualitative description of guidelines in implementing the solution

Table 6 Design of the Research Questions

1.4.4 Deliverables

As soon as the research questions are answered by means of the said research design, the outcomes can be used to perform the DSRM. Table 7 portrays the correspondence between research questions and the deliverables.

Research Question	Corresponding Deliverable	Deliverable Definition
1	Languages Overview	A comprehensive summary of the most used modelling languages in the field of business process modelling
2	Solution Objectives	The qualitative and quantitative criteria which the reengineered EDCP should comply with.
3	DCP Landscape	Process Diagram of the DCP internal and external, supplier and customer processes
	As-Is EDCP process	Outline human activities and application support with enough detail to understand what operations depend on the ERP configuration and their completion time
	As-Is Order E/R Diagram	Outline of the entity relationship diagram of the custom bike order, and its consequent effect on the EDCP
4	Bottleneck Analysis	Report of the throughput time of the EDCP activities and display of their ranking accordingly.
5	To-Be EDCP business and application levels	Reengineered EDCP business and application level with the ERP new logical workflow, the new application stack, and the performance analysis
6	Most Desirable reengineered process	Analysis of decision maker preferences by means of systematic quantitative techniques. The process aims at establishing a rank of importance of the solutions
7	Implementation Plan	Strategy to be followed in order to technically implement the best architecture in practice

Table 7 Research Deliverables

2. Literature Review

Before delving into any elaboration, it is reasonable to outline the results of literature searches for they will serve as a theoretical foundation to the following. Henceforth, RQ 1 is answered as a standalone literature review and its search strategy is given in appendix C.1. However, despite its relevance, no overview of ERP structure is included, but an unexperienced reader is referenced to Kurbel (2013, p. 95) and Weske (2007, p. 49) for information.

On high level of abstraction, the field of Business Process Modelling partitions into diagrammatic, mathematical, and linguistic models (ShishKov, 2017). The latter category is the most recent and most relevant for industrial applications (Kappel et al., 2000). On its turn, it splits into rule-based and graph-based models where the former consists of encoded computerized scripts and the latter stands for visual representation ontologies (Lu & Sadiq, 2007). Within this latter subcategory, more differentiations exist. Firstly, traditional models, such as Event Driven Process Chains (EPC) aim at communicability. Unified Modelling Language (UML) belongs to the object-oriented representations, and they are derived from the field of software engineering. Finally, Business Process Modelling Notation is an example of the industry developed semantics, which aims to serve both the previous purposes (Mill et al., 2010).

Regarding graph-based models, a large variety of process languages have been developed in literature (Garcia-Borgonon, 2014). However, on the basis of comparative scientific analyses, this compendium considers Business Process Modelling Notation 2.0 (BPMN 2.0) with its expansions as identified by Zaroru et al. (2009), Process-Oriented Methods and Tools for Knowledge Management (PROMOTE), Knowledge Modelling and Description Language 2.2 (KMDL 2.2), Oliveira’s Methodology (Oliveira), Event Driven Process Chains with their extensions (Baier et al, 2010; Ben Hassen et al., 2017), Unified Modelling Language and its augmentations (Gill, 2015; Ben Hassen et al., 2018), Role Activity Diagram (RAD) (M. Ben Hassen et al., 2018; Pereira & Silva, 2016), Integration DRFinition (IDEF) (Pereira & Silva, 2016), Petri Nets with their improvements (Braghetto et al., 2010; Shih & Leung, 1997; Recker et al., 2009), ArchiMate with its integrations (Gill, 2015), Yet another Workflow Language (YAWL) (Hence & Malz, 2015; Figl, 2010), Subject-Oriented Business Models (S-BPM) (Hence & Malz, 2015; Gill, 2015) and a selection of performance analysis languages (Braghetto et al., 2010) as the most important ones.

After a secondary literature analysis, it appears that these languages can be clustered against two dimensions. The y-axis of figure 5 represents how much the notation has semantic elements to capture information flow dynamics. On the sampled papers, this element was measured as the ontology’s score under the informational perspective of the Business Process Meta-model for Knowledge Identification (BPM4KI) (Turki et al., 2016). On the other hand, figure 5 x-axis reports the extent to which the language can explicit processual dynamics. Again, this element was operationalized as the score under the BPM4KI operational perspective (Turki et al., 2016; M. Ben Hassen et al., 2018).

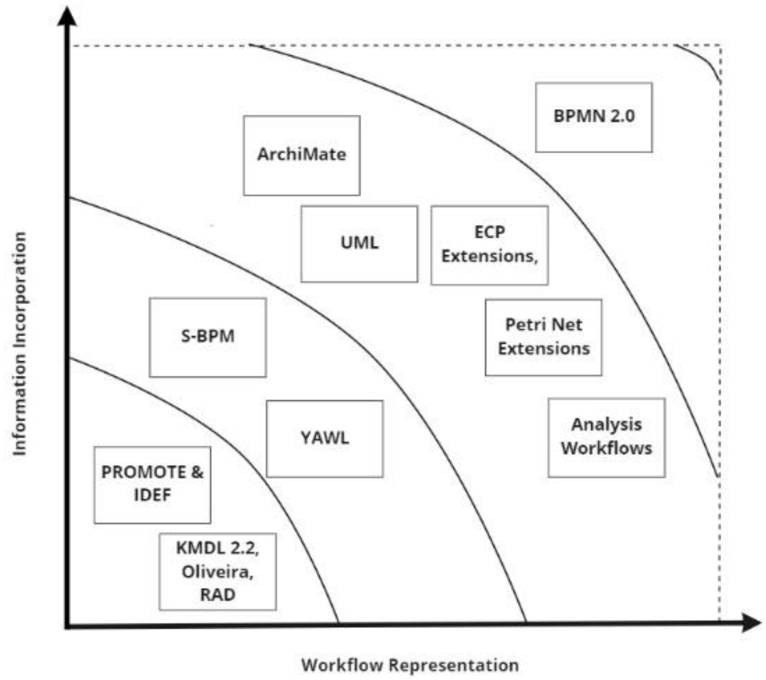

Figure 5 Summary of business process languages

Given the need to model the enterprise architecture (EA) level along with the business and application processes, ArchiMate has been chosen as the most suitable modelling language for this study. The inexpert reader is referenced to The Open Group (2021), Lankhorst et al. (2009), Josey et al. (2016) and Polyvyanyy et al. (2009) for an overview of this modelling language.

3. Solution Requirements

The solution requirements are treated before the solution development for two reasons. Firstly, it helps preventing psychological bias in solution selection (Heerkens & Van Winden, 2021, p. 76). Then, it is essential for the objective embodiment in the design process of DSRM as pointed out also by the BABOK methodology (Hailes, 2014, p. 62). In this step, the problem owner is interviewed to discover which characteristics a new enterprise architecture must present to be attractive and answer RQ 2. As follows, the results are outlined, defined, and operationalized to guide the target architecture development process in more detail.

3.1 Defining Solution Objectives

To start with, four features were deemed relevant by the problem owner. Firstly, a new ERP architecture ought to reduce the EDCP throughput time by at least 43%, which is to say that it should solve the core problem. Moreover, while tackling the managerial dilemma, other three requirements ought to be met. The solution should be as cheap as possible to implement, it should be easily modifiable for maintenance's sake and it should be resistant to malicious breach attempts. These properties are listed and defined in table 8. Albeit uttered by the Production Manager, most of these definitions align with literature concepts. Thus, citations are added too. Moreover, the rightmost column of the table portrays attributes importance in percentage. Section 6 with appendix F report the process of weights determination.

Attribute	Definition	Importance

Performance	Reduction in throughput time in a standard execution of the process blueprint (Ceci et al., 2014)	53,4%
Cost	Monetary expenditure connected to the implementation of the target architecture (Heerkens and Van Winden, 2021, p. 77)	26,7%
Modifiability	Effort required to correct, improve, or vary a software system to adapt it to changes in its working environment (Bengtsson et al., 2000)	10,2%
Resilience	Ability to absorb the impact of a problem in a part of the system while continuing to serve the business adequately (Curtis, 2010)	9,6%

Table 8 Solution Objectives

Therefore, Bianchi envisions a reconfigured ERP system which can decrease the throughput time of the DCP foremostly. Secondly, it is important that the variation is cheap to implement. Moreover, the intervention should be modifiable for maintenance and resilient to malicious attacks.

3.2 Turning Objectives into Practical Requirements

Next, scaling attributes can greatly help to guide the solution generation process. As follows, the reader is explained why this is the case and what operationalization best fits the criteria at hand. Again, each of them is measured by means of one indicator only, as suggested by Heerkens and Van Winden (2021, p. 56). Since these metrices are developed solely for comparison among processes, it is not important to standardize them as if they had to be compared against each other (Cooper & Shindler, 2006, p. 271).

In fact, an operationalization clarifies how reengineered processes map onto the decision metrics and consequently it sheds light on the desirability of solutions. However, variables are traditionally operationalized in a rather universal manner, for instance, performance is measured as cycle time and cost in euros (Slack et al, 2010, p. 48). On the contrary, if operationalizations were based on the process structural properties, they would substantiate the link between them and the decision criteria. This means that they would give profound insight in what architectural specimens are to be varied to increase the system desirability and so, these type of operationalizations are preferable in a design project.

3.2.1 Operationalize Performance

In this regard, literature offers abundant measurements of this kind. To start with, the DYNAMO framework is possibly the most widespread one to measure the performance (PF) of an IT process (Granell et al., 2007). In line with the methodology, each EDCP activity is decomposed in its processual tasks, and these are scored according to table 9. Then, unlike the DYNAMO method, their average is taken as indication of the overall automation level. Eventually, the performance of an activity is tracked as PF which is computed with equation 1.

$$PF = \frac{1}{n}\sum_{i=1}^{n} d_i \qquad \text{Eq 1}$$

Where $n \in \mathbb{N}$ is the number of sub activities within the task, and d_i is the automation level of the ith sub activity as gained from table 9 for each i. Thus, performance is tracked as mean automation level, and PF is measured as the mean automation rank of the process tasks, and its measurement unit is mechanization level. Overall, the higher eq. 1 scores, the greater PF, and the more an EA is valuable.

State	Information Control Condition	d_i

Totally Manual	The user understands the situation and creates his/her course of action completely autonomously	1
Decision Giving	The user receives information or a suggestion about how the task can be achieved	2
Teaching	The user gets instructions about how the task can be achieved optimally	3
Questioning	The technology questions the execution if the execution deviates from what the technology finds appropriate	4
Supervision	The technology calls for the user's attention and directs it to the best course of action	5
Intervene	The technology takes over and corrects the action if the execution deviates from what the technology considers suitable	6
Totally Automatic	All the information and controls are handled by the technology, the user is never involved	7

Table 9 DYNAMO Information Control Automation Levels (Granell et al., 2007)

3.2.2 Operationalize Cost

Briefly, Unadjusted Function (UF) Points are arrived at by counting the number of software components that belong to five categories – inputs, outputs, inner directories, outer repositories, and inquiries -, and combining them linearly with weights relative to their complexity (Finnie et al., 1997). However, the determination of the weights is taxing and inappropriate for an iterative execution throughout the design process (Ahn et al., 2003). At the same time, the description of UFs entails that the simple sum of the architecture components can explain the implementation costs (CS) to some extent. Such formula would be simple enough to be used iteratively and thus, the implementation cost is tracked by means of the architecture complexity, which is measured by equation 2:

$$CS = z_1 + z_2 + \cdots z_5 \qquad \text{Eq 2}$$

Where $z_i \in \mathbb{N}$ is the number of components type i in the system for every i appearing in table 10. Hence, cost is measured using the number of components in the system as measurement unit. Note that it will be named "complexity" as well henceforth. For this metric, the higher the score, the greater CS, and the lower the EA desirability.

Component	Description	Index (i)
External Inputs	Process that intakes inputs from outside the boundaries of the system – such as user input screen.	1
External Outputs	Process which passes data to an application outside the boundaries of the system – reports or output screens are examples.	2
Internal Logic Files	Group of interrelated data in the system – databases and data warehouses are instances.	3
External Logic Files	Group of interrelated data outside the boundaries of the system which interacts with the system – such as external databases.	4
Inquiries	Process of extracting data from the internal and external logic files – queries are examples of this category.	5

Table 10 Architecture Component Categories in Function Point Analysis (Finnie et al., 1997)

3.2.3 Operationalize Modifiability

Although a sley of methods have been devised to assess software modifiability, most of them seem intractable for an iterative application in the design process (Lagestrom et al., 2010). Far from impracticality, Light (2001) categorized and ranked ERP post-implementation variations according to their required maintenance effort. Since this idea convolutes corrective, perfective, and adaptive actions, this frame applies in this paper too and it can be used to construct an indicator of modifiability. Hence, a given process can be examined to evaluate how many elements it uses from 5 categories – new displays, amended reports, automated logics, new functionalities and changed software, Next, these quantities can be linearly averaged by their modifiability scores to gain the average value of the system:

$$MD = \frac{\sum_{i=1}^{5} i * n_i}{\sum_{i=1}^{5} n_i} \quad \text{Eq 3}$$

Where n_i is the number of architecture components which fall in category i for each i in table 11. Also, i corresponds with the modifiability grade which Light (2001) assigned to customization classes. In this table high rank numbers are given to classes that make it difficult to insert additional customizations in a proportional manner. Hence, this statistic is measured as the mean modifiability rank of the system components, and maintenance level is its measurement unit on this artificial scale. However, if $\sum_{i=1}^{5} n_i = 0$, it is reasonable to set $MD = 1$ because it means that no architectural component belongs to these classes, thus the ERP is still uncustomed, and its ease of modification is highest. In this indicator, the higher the score, the lower the ease of modifiability, and the slighter the EA attractiveness

Post Implementation Category	**Index (i)**
Create new reports or displays	1
Amend reports of displays	2
Automate process logic	3
Add software functionality	4
Change software functionality	5

Table 11 ERP post implementation categories (Light, 2001)

3.2.4 Operationalize Resilience

Finally, resilience (RE) can be scored as systemic compliance with robust structural features. In fact, many software development organizations have output manuals on how to integrate resilience within a software architecture (Ford et al., 2013). In particular, the Consortium for Information and Software Quality created a list of 12 properties which systems should try to achieve to increase resilience (Curtis, 2010). Although most of them are to be implemented upon technology deployment, three can be planned in the preliminary architecture. Since they are not mutually exclusive, an architecture resilience can be indicated by how many of these factors it incorporates. Thus, given an architecture, for each feature, the number of places where it could be implemented can be identified by a contingent analysis. Then, the fraction of locations where it is actually present is taken as percentage and they are averaged to obtain the RE:

$$RE = \frac{1}{3}(p_1 + p_2 + p_3) \quad \text{Eq 4}$$

With p_i that tracks what proportion of places suitable for implementing condition i was subject to its deployment, for each i of table 12. Thus, resilience is scored as the proportion of elements where this property could be implemented, rather than having a usual measurement unit. Finally, the higher eq. 4 , the greater the RE, and the more the EA is desirable.

Resilience Property	Description	Index (i)
Redundancy for Backup	Duplication of services or components to enable a backup option when a component fails	1
Data Caching	Architecture component that stores data to serve future request of that information faster and offer a backup for default occasions	2
Input Vetting	Evaluation of all user inputs to verify that they are neither harmful nor malicious	3

Table 12 Operationalization of Resilience (Curtis, 2010)

To conclude, the solution objectives of performance, cost, modifiability, and resilience can be synthetized into four practical requirements. The first is automating the process information controls. Then, reducing the architectural elements, minimizing the variations in the architecture structure and ensure resilience of new components are the remaining three. Lastly, it would be possible to synthetise these scores into a single indicator by multiplying them with their weights and summing the results. This process is carried out after the target processes are outlined to suggest the optimal one.

4. Process Baseline

After the preliminary outline of process practical requirements, the current state of the workflow is to be investigated. In what follows, the process landscape is firstly explored to answer RQ 3. Then, the single activities are studied in greater detail and scored against the metrices of section 3.2.1 through 3.2.4 to perform the gap analysis and reply to RQ4. As of this section, all the visual models have been validated through discussion with the production planners on multiple occasions.

4.1 Process Landscape

The first important step toward the completion of DSRM phase 3 is portraying the DCP landscape, which is carried out in section 4.1.2. However, to facilitate the reader's comprehension of subsequent discussions, a relevant portion of the ERP data structure is depicted in section 4.1.1.

4.1.1 Order Data Structure

In fact, envisaging the relevant order data structure will familiarize the reader with the lingo to be used. Therefore, figure 6 depicts it in Crow's foot notation, and it has been validated by inspection of the production planners. In this image, primary keys are in bold fonts, foreign keys are in italics and attributes which have neither of these roles are expressed in normal characters.

To start with, the ERP has a repository of products uniquely identified by their alphanumeric identities. Among their attributes, products have structures, and, more importantly, locations. This attribute expresses the good current ubication which must be updated iteratively as the products go through the production processes. Then, the database (DB) allows the insertion of customers, who are identified by an integer and linked to multiple data such as billing and delivery address.

Next, upon demand arrival, customer orders (CO) can be instantiated in the ERP, and they relate to multiple order lines, and to the ID of the customer who performed the order. As of order lines, they capture the products which the ordering client demanded, along with other data such as their quantities. Next, for accountability purposes, distribution orders (DO) convolute all the lines about the same good into scheduled movements of product among warehouse locations. However, as the circulation requires material, the manufacturing orders (MO) schedule production for the quantity needed to satisfy the DO. Therefore, COs are sets of order lines coupled by information related to payments and delivery. Order lines are products that clients demanded simultaneously with selling prices and quantities, whereas products are bikes or components which dealers can purchase at the factory.

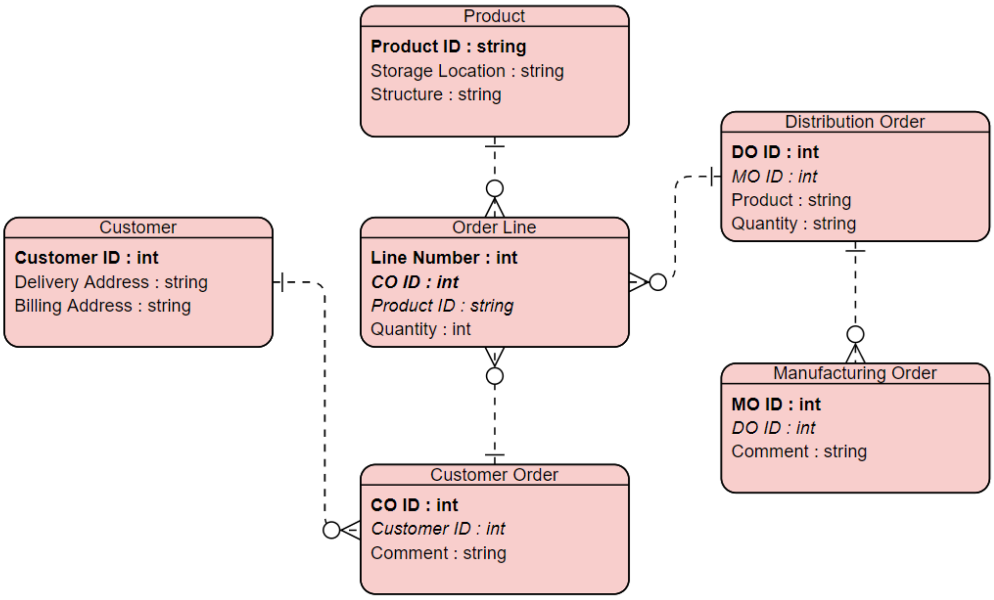

Figure 6 ERP Order Data Structure

4.1.2 DCP Landscape

As of the DCP itself, section 1.1.2 has already introduced it from a subject oriented perspective as a matter of fact. Now, figure 7 adopts a business process view and examines its internal and external landscapes in a more refined level of abstraction. Within the role tab "Production Planner", the DCP inner tasks are portrayed, while its external links are captured in the rest of the figure. As of its internal activities, white notes depict the condition under which they are enabled.

Throughout the week, distributors place orders for bicycles. If these demands concern customizable bicycles (CBs) however, there is no production plan based on which the commercial unit can promise shipments. Thus, this function reacts to the arrival of a CB order simply by inserting a CO in the ERP. Then, they wait for the planning division to decide when the goods can be produced. Once a week, a production planner takes vision of all the COs arrived in respect to custom bikes. This employee schedules their production according to the availability given by the ERP system. Then he sends back the information to the commercial department which updates budget parameters and subtracts the newly inserted goods from the production forecast quantities. The assembly date is also shared with the supply chain function, which organizes the outbound transportation and communicates when the delivery will occur. Then, thanks to this insight, the commercial unit can finally give feedback to the distributor. In the meantime, the planner keeps an overview of custom COs in process in his excel file. Here, he organized outgoing and incoming material both toward and from external painting stations. Once established date, location and quantity of the deliveries, these actions are practically carried out by warehouse operations. As soon as the customized material is received or delivered, it is signalled to the planning operator who updates the ERP accountability once more. Next, the production manager is notified, and he updates the assembly schedule to make room for the custom bikes. Figure 7 shows this process and tasks with bumblebee yellow background are the DCP activities, for these activities, white boxes contain the input data requirements. Hence, they are further analysed to subside the operational distress of the planning department. It is now anticipated that, out of these activities, the ERP supports all the tasks of the production planner except for “Update Others”. In fact, this job only entails emailing the supply chain function and the sales accountant with how the MOs and the DOs have been updated, out of the DCP activities Therefore, “Update MOs and DOs”, “Update Excel”, and “Transportation Tasks” form the EDCP and thus, the bottlenecks shall be identified among them.

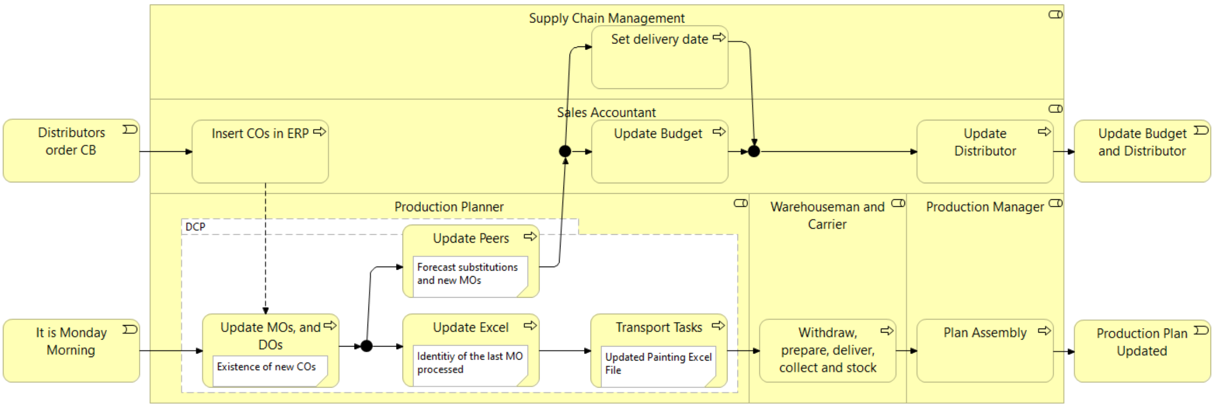

Figure 7 DCP Landscape

4.2 Tasks Baseline

Once the DCP landscape has been mapped, RQ 3 must be answered by taking a closer look at the EDCP activities, which are “Update Mos and DOs”, “Update Excel”, and “Transport Tasks”. Within this examination, the ArchiMate “Realization Viewpoint” is adopted because the focus was set to business and application layer in section 1.4.2. For brevity purposes, the reader will see notations such as A2.1 in the ensuing analysis. Such jargon references to an activity, and in this case, it is to be read as “As-Is Activity 2 subtask 1”. From time to time, process stages will be encoded in this notation.

4.2.1 As-Is Update Manufacturing and Distribution Orders

As Monday morning comes, the production planner runs an extraction query which fills an excel table with all the COs still to be delivered from the ERP (A1.1). Then, data manipulation enables to identify only the custom bicycles left to manufacture (A1.2). As this step is over, the ERP is opened to visualize what forecasted bicycles are still to be produced. Among these instances, the operator searches a bike compatible with the customizable one and notes down its details (A1.3). Subsequently, he creates the manufacturing order and the distribution order for the configurable product, by means of the apposite ERP windows (A1.4). Now he can take the identification of these instantiations (A1.5) and send them to the commercial department together with the credentials of the forecast slot used – which is what occurs in “Update Others”, in figure 7. The sales accountant will use this information to update the forecast slots manually and make budgeting analysis for the future. Then, another CB is picked, moving from oldest to newest and the process iterates. As soon as it is over, the ERP account is updated, and the substitutions are performed as it can be seen in figure 8.

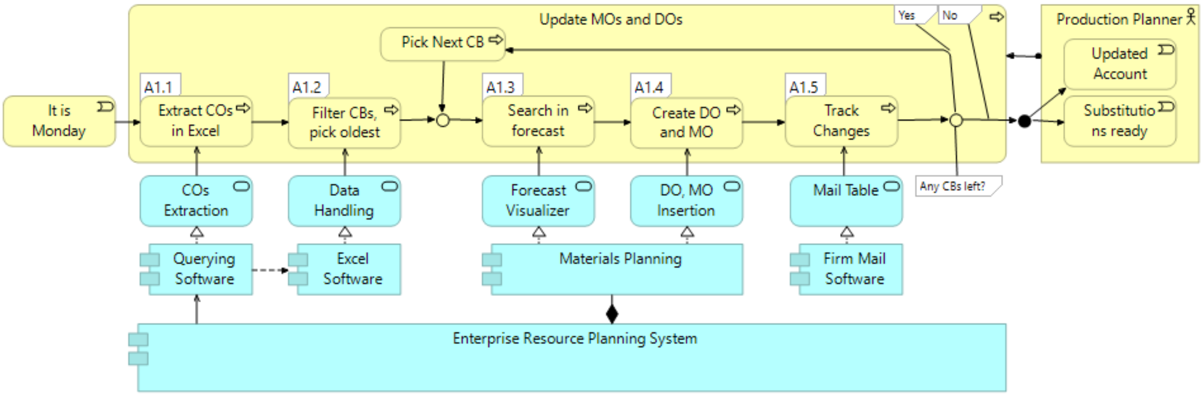

Figure 8 Update Manufacturing and Distribution Orders Baseline

4.2.2 As-Is Update Excel

When the process in figure 8 ends, the planner runs an ad-hoc script that transcripts all the order data from a CO to the corresponding MO (A2.1). Then, all the MOs are extracted in excel (A2.2), and those for custom bicycles are filtered (A2.3). However, since some data fields are truncated, the MOs are extracted again through an ERP query, and the excel file is completed (A2.4). Finally, for each row in the document, the encoded bike configuration is spelled out to serve supplier communication (A2.5), and figure 9 reports this process encompassing the application stack.

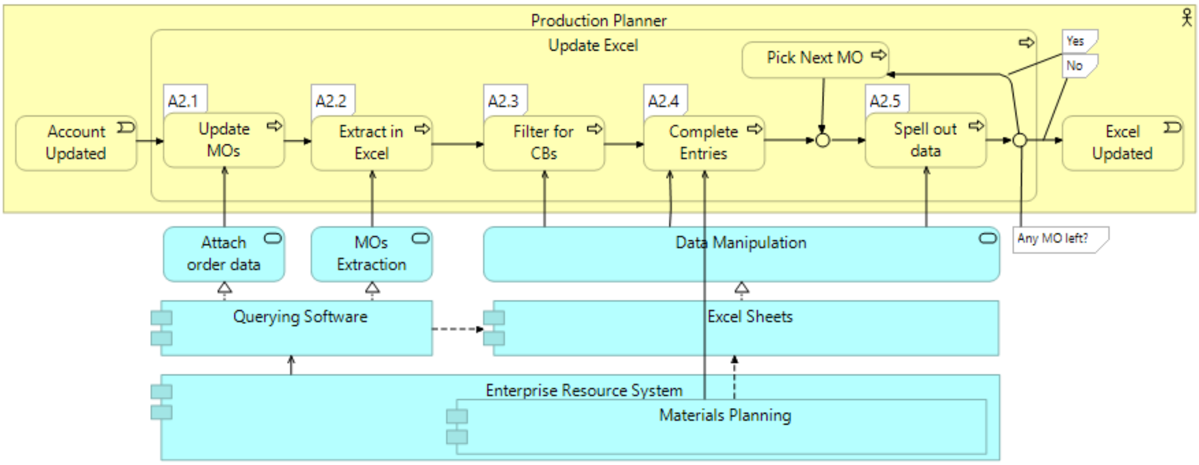

Figure 9 Update Excel Baseline

4.2.3 As-Is Transport Tasks

When the excel file displays all the new CBs, the transportation can be arranged in the manner portrayed by figure 10. First, since different painters can fashion different ranges of configurations, the planner groups the outgoing bikes by the external operator they can go to (A3.1). Then, availability is asked on the phone and within the same call, both the outgoing shipments and the incoming collections are agreed with the colourist (A3.2). Next, the painter and the carrier are given detailed information about volumes and times of the inbound and outbound transportations by email (A3.3). When this passage is over, the movements of material are signalled in the ERP system and a withdrawal list is printed for each painter (A3.4). This information is requisite to guide warehousemen in their operations and it displays all the material shipped toward one destination. Then, the same information is transcript onto a travel note into the ERP, and this legal artefact is printed (A3.5).

Eventually, for each outgoing bike, an image of its design is printed from an online repository and attached to the shipping box (A3.6).

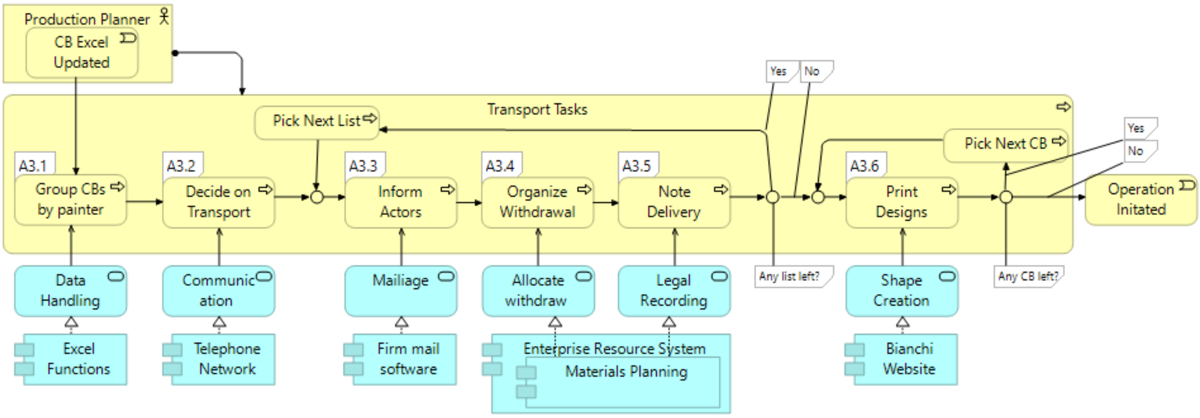

Figure 10 Transport Tasks Baseline

4.3 Performance Analysis

Henceforth, to answer RQ 4, activities durations are listed, and, whenever possible, the solution requirements are scored to enable comparison with the target architectures. This is carried out for "Update MOs and DOs", "Update Excel" and "Transportation Tasks" in table 13, 14 and 15 respectively.

Clearly, duration recordings are to be reported because they are strong premises on which to base the solution development. In fact, ideally, the longer an activity, the more radical its solution can be. Less intuitively, solutions objectives are to be scored on the current processes as well. Despite the effort required for the quantification of the as-is workflows, this action is needed because the target architectures must score higher than their present counterparts to be desirable. As of the to-be processes duration, it can be argued that if the future architectures have better performance than their present forms, their throughput time will be lower, as explained in section 3.2.1. Nevertheless, the price correspondent to the variations should be assessed, and given the metrices in use, this requires the present price of the system to be envisioned too. Moreover, since the effect of the improved performance on resilience and modifiability might be negative enough to offset the benefits, these variables change should be monitored. Therefore, the baseline scores should be measured so that consequently, the to-be processes can be developed and whether they are better than their current equals can be established.

In regard of duration, the reader is referenced to appendix D.5 for an overview of the data gathered and how it was morphed into tables 13 through 15. Here, it is important to mention that self-reported duration is tracked in seconds per bike and rounded up to the closest integer, so comparisons among activities is feasible. Before collecting data, the processes were split in macro sections. First, as of "Update MOs and DOs", two fragments are measured, and they convolute A1.1 to A1.2 and A1.3 to A1.5. Then, "Update Excel" was divided into two segments, with the first including A2.1 to A2.4 and the second being A2.5. Finally, "Transport Tasks" was split into three abstract chunks, spanning from A3.1 to A3.2, A3.3 to A3.5 with A3.6 alone being the last. Subsequently, production planners self-reported the duration of each set of activities according to the throughput unit flowing though those tasks, and the cycle time per bike was derived statistically. As of scoring the solution objectives, the computations for performance, cost, modifiability, and resilience, are to be found in appendix D.1, D.2, D.3, and D.4 respectively. These paragraphs report scores for each subcomponent of the metrices mentioned in sections 3.2.1 through 3.2.4, and they are coupled with motivations for assigning that grade. Hopefully, such illustration suffices to motivate the scores in the subsequent tables and henceforth, sole data interpretation suffices for comprehensiveness. Noticeability, for each indicator, results are rounded up to the first decimal.

Regarding the analysis of “Update MOs and DOs”, together with the “Update Excel” task, it is the most robust process. In fact, it presents resilience features in 66% of the segments where input vetting, caching and data redundancy could have been implemented. Moreover, it is the second in performance, cost, and total duration. As of the first, the average information control automation level of its components is 2,6 when scored according to the DYNAMO methodology (Granell et al., 2007). Secondly, although implementation cost should be of little interest for an existing system, this metric track complexity too and such attribute is important for comparison with the target architecture. In this case, a cost of 20 entails that this system is composed of 20 distinct components according to the taxonomy of IT elements given by Finnie et al., (1997). In addition, the planner responsible for this process reported that the duration of tasks A1.1 to A1.5 is in total between 162 and 183 seconds per bicycle. Finally, modifiability attains a value of 3 here. In other words, the ERP system was variated in some of its components, and altogether, these variations result in a difficult of 3 to add other changes according to the modifiability developed by Light (2001). Noticeably, this value is rather low, indicating a high modifiability. Table 13 summarized this data.

Performance	Cost	Modifiability	Resilience	Self-reported Duration	
				A1.1-A1.2	A1.3-A1.5
2,6	20	3	66%	2-3	160-180

Table 13 Score Report of Update Manufacturing and Distribution Orders Baseline

Likewise, the values in table 14 can be interpreted in a similar fashion. Firstly, “Update Excel” has the briefest duration among the three activities, meaning that the overall self-reported throughput time is between 83 and 104 seconds per bike. Yet, its performance is the scarcest because the average automation level of information controls is 2,4. This counterintuitive fact may be justified by the process complexity, which is also the lowest among the three as the architecture is made of 19 distinct instances. Moreover, the resilience scores as high as that of “Update MOs and DOs” since its instances were implemented in the 66% of the components where they could have been. Finally, modifiability scores 2, indicating that it will be very easy to add another customization layer or to change the process application stack in the future.

Performance	Cost	Modifiability	Resilience	Self-reported Duration	
				A2.1-A2.4	A2.5
2,4	19	2	66%	3-4	80-100

Table 14 Score Report of Update Excel Baseline

Lastly, table 15 elaborates on the scores of “Transport Tasks” and a few facts are to be noted. First, despite it enjoys the highest degree of performance, its complexity is the greatest among the three activities in analysis. As a matter of fact, its mean level of control information flows automation is 2,7 while it is composed of 25 different architectural elements. Furthermore, its resilience attains the minimum in comparison with the other, since only the 33% of the components which could support resilient implementations were used to this purpose. Moreover, despite it scores the worst in modifiability, its grade is still rather low in comparison to what it could be, and the total self-reported duration is second only to that of “Update MOs and DOs”.

Performance	Cost	Modifiability	Resilience	Self-reported Duration

2,7	25	5	33%	A3.1-A3.2 7-17	A3.3-A3.5 38-49	A3.6 80-100

Table 15 Score Report of Transport Tasks Baseline

Therefore, the answer to research question 4 is that within "Update MOs and DOs", the process segment between "Search in Forecast" and "Track Changes" is the greatest bottleneck. Meanwhile, in "Update Excel", the spelling out of data is the most time-consuming activity, while in "Transportation Tasks" printing designs is the largest bottleneck.

To sum up, given that "Update MOs and DOs" essentially updates the ERP DB, a cost of 20 is rather high. Likewise, 19 is an elevated expenditure figure for a process that tracks changes on an excel sheet and 25 is exorbitant for organizing the transportation of goods. Hence, all CS scores ought to be reduced, and the same holds for the MD indicator of "Update MOs and DOs", "Update Excel", and "Transport Tasks". Recall that le lower the value of this metric, the higher the ease of modification. For this indicator, these processes have mean levels of 3, 2, and 5, which shows that there exists some customization already. However, the tailoring does not serve the process well given the 43% DR reduction need, and it should thus be changed. With regard to RE, that of "Transport Tasks" ought to increase, not only because it is currently the lowest, but also because logistic documentation is legally binding and thus, it requires more protection. As of performance, given the correlation that Granell et al. (2007) found between process automation and throughput time, the best strategy to reduce DR is increasing the PF metric for all the processes, regardless of their current score. These are the practical objectives of the reengineering effort.

Furthermore, the reader should notice several facts. Firstly, a visual inspection of the process maps hints to the vastity of the human performed activities. This itself may not be an issue but evidence supports its contribution to enhance process completion time (Heckman, 1976). Secondly, the modelling effort was focused at capturing the so called "Happy Path". In fact, since process exceptions are not the research focus in this case, clarity requires error handling to be omitted from the visual representations (Havey, 2006; Kurz et al., 2013). Thus, occurrences such as delay of production or backlogs handling are not modelled, although they do occur sometimes. This focus on happy flow also dominates the creation of target architectures. Lastly, in order to increase the probability of suggesting a solution that attains a 43% duration reduction, a target architecture is proposed for each task in the subsequent section.

5. Target Process

To derive target improved processes, it is important to enumerate what can be varied in the DCP related architecture. This information is expanded in section 5.1 along with the creativity method used for the development. Section 5.2 depicts the result of such procedure, their scores, and arguments for their optimality. Overall, this passage aims to answer RQ 5 and to carry out DSRM step 3.

5.1 Solutions Generation Methodology

Now that the routines have been abstracted into their workflows, solutions can be generated on the immaterial level of ArchiMate process models by varying the as-is representations. However, how these models can be variated should be investigated before undertaking the development process.

5.1.1 Solution Instruments

To start with, in respect of structural changes, the ERP can be largely modified, despite the monolithic database which enables no variations. First, it has off-the-shelf configurable parameters within each mask. Then, it includes a mashup tool which allows the creation of new interactive screens, it has a scripting apparatus which enables the customization of existing logical dynamics and, it has a communication channel which permits to share information with external applications. This last element consents to outsource tasks outside the system, and thus a discussion of ERP variations would not be complete without treating architectural changes in a broader sense. Among the external software which can be used to integrate the ERP, this research conceptualizes three classes: external databases, online applications, and computational software as inspired by (Light, 2001). Each of the element named in this section was carefully studied to identify how it could be used, as to ensure the feasibility of the solutions entailing their use.

5.1.2 Solution Methodology

Now that what can be varied is outlined and how it can be changes is clear, table 16 reports a systematic technique to carry out the ideation process and its steps are listed in chronological order. At least three motives make it important to approach the solution generation with a deliberate development strategy. On the one hand, it makes it more likely that eventually the duration reduction amounts to 43%, as the core problem calls for in table 3. On the other hand, it ensures that the importance of the objective criteria is considered throughout the creation. Finally, it fosters the comprehensiveness of the generation process because it leads to explore the solution space more thoroughly.

- Pick one EDCP task
  - Use Duration to pick the longest process chunk
    - Reengineer its underlying architecture to optimize its cost and its performance metrices
    - Make minor adjustments to increase its modifiability and resilience indicators
  - Pick the process chunk with longest duration among the remaining ones and iterate
  - Unify the reengineered architectures behind process chunks into one
  - Depict the resulting model using ArchiMate
- Pick another EDCP task and iterate

Table 16 High Level Ideation Methodology

First, an abstract process model is selected among those of the EDCP tasks as illustrated in section 4.2.1 to 4.2.3. Then, its corresponding table of scores is visualized as reported in section 4.2.4. In particular, the rightmost column is envisioned and among its partitions, that with longest self-reported duration is handpicked among those which are still to be treated. As a result, within an EDCP task, the remaining subset of activities with largest completion time is designated for elaboration. Then, given how the instruments of section 5.1.1 could be used, they were used to reengineer the IT architecture underlying the selected process chunk. At first, the purpose was to redesign the system section radically as to improve its scores in the cost and performance metrices described in section 3.2.1 and 3.2.2. Then, minor variations were feasible to improve its grades with respect to modifiability and resilience as computed in sections 3.2.3 and 3.2.4. As these actions were over, another process chunk was taken from the task table of section 4.2.4 and the local development was repeated until each of them had been redesigned. Consequently, given the detached ameliorations, they were synthetized, integrated, and connected to form a unique architecture. This process was carried out so that the longer a process chunk duration was, the less its underlying reengineered system would have been changed for incorporation purposes. Moreover, the combination aimed to ensure cohesion of systematic components too. In the end, three comprehensively redesigned architectures were output, each for one EDCP task and they are reported in section 5.2.1 through 5.2.3. These representations are coupled with their scores on cost, modifiability, resilience, and performance indicators to substantiate the overall 43% reduction in duration and their individual quality.

To conclude, as of the business process, there are no non-value adding activities to be erased from the start. However, it is possible that when the Enterprise Architecture (EA) is varied, some business and application elements become ultimately unnecessary. Therefore, models will not be directly reduced, unless it occurs because of other interventions. Moreover, the heuristic applied to generate solutions favours the integration of services within the ERP rather than outsourcing them. In fact, in terms of performance, centralizing the IT processes reduces time for digital communication and enables to capitalize on the structural properties of the system. As of cost, the firm can have them implemented by the internal IT department, while if an architecture grows too complex, its creation has to be subcontracted. Moreover, modifiability benefits from an internal implementation because distributed systems tend to require enormous efforts to align upon maintenance and resilience would enjoy the digital protection of the ERP access barriers.

5.2 Target Processes Outline

As follows the reader is presented the target processes. It is important to notice that the feasibility of what is explained henceforth has been validated by discussion with the IT department. Also, in the following, the reader will see expression such as T3.2, such phrase is to be read as "Target architecture of EDCP process 1, task 2". From time to time, these names are assigned to set of activities. If activities are mentioned with no name next to them, it means that they have been aggregated in the upcoming declared name. The reader will find rather precise results for the scoring of the processual indicators. These values were obtained using equations 1, 2, 3 and 4 on the data gathered in appendices E.1, E.2, E.3 and E.4 respectively. For instance, appendix E.1 scores the variables at the right-hand side of equation 1 for every target process, and it explains how these numbers were convoluted into the performance scores. Likewise, section E.2, E.3 and E.4 gather analogous explanations on the use of equations 2, 3 and 4 to evaluate cost, modifiability, and resilience of the to-be processes. Because of their length, these elaborations are not included in the single subsequent passages. Also, in general, the variation in score of an indicator for a process model is measured as that indicator value in the target architecture, divided by its value in the corresponding baseline process, minus one.

5.2.1 To-Be Update Manufacturing and Distribution Orders

As of "Update MOs and DOs", the reengineering aim was using the ERP scripting tool to automate the production planner tasks and excise him from the process. This would not only increase PF which now is 2,6, but it would also attain a CS lower than 20, as better collaborations among software components can be designed. In fact, as the commercial department opens the demand-insertion screen, a script is loaded and when a CO is added, the routine triggers. Ideally, the script saves the CO number and reads its first line (T1.1). Then, if it is a custom bike, it queries the forecast to retrieve the earliest available slot for its production, it stores its date and its tracks its bike type (T1.2). Then, it uses ERP inbuilt application program interfaces (APIs) to create the DO and the MO (T1.3) corresponding to the custom bike order with the CB code in the MO comment, and it reduces the forecast left for selected date (T1.4). The script ought to loop over all the lines with this same procedure and as no more rows are left, it returns all the changes made in the forecast to by means of a pop-up screen (T1.5). This enables to track what occurred with great precision, which enables to perform accountancy analysis in later stages. As the operator takes notice of the variations, the window with the annotations can be closed and the procedure ends. Eventually, the MOs and the DOs are updated inasmuch as they are created, and their corresponding product is removed from the forecasted quantity. Also, step T1.4 updates the forecast automatically, which currently is a manual task performed by the sales accountant.

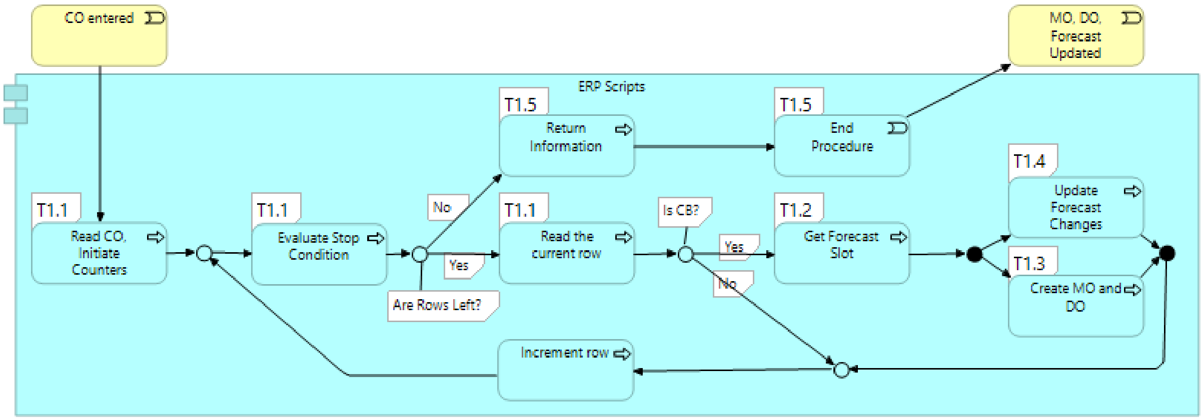

Figure 11 Target Update Manufacturing and Distribution Orders

5.2.2 To-Be Excel Update

Subsequently, the improvement of "Update Excel" aims to integrate and automate the excel manipulation into the ERP. In this case, PF should increase as the mechanization level grows. Meanwhile, CS would decrease as the excel software is removed from the system. However, MD could drop as the ERP must be added data extraction functionalities, as illustrated in the following. To do this, a new display must be mashed up in the ERP opening screen, and in the easiest version, it should just consist of a table analogous to the current excel one. Even though the mashup itself can be programmed with some back-end logics, it is best to populate the table by means of a custom ERP script, where application program interfaces can be coupled with some lines of ad-hoc code (T2.1). This way it can be ensured that MOs are not retrieved solely within a time period, but they are also filtered to screen out standard bikes. Then, as manufacturing orders are retrieved, another script should translate the configuration code in their comment into a verbal description of the bike aesthetics and paste it in the table columns (T2.2). Eventually, bicycles' locations are to be monitored but the ERP data structure makes this step fairly cumbersome. The problem with tracking CB positions is that the ERP movements list identifies bikes by means of their size, model and whether they are customizable, it does not distinguish their configuration code. Thus, if two CBs had the same type and size, but different customizations, a query would retrieve them both since inquiries over configurations are unfeasible. Hence, for each CB in the table, the rightmost column can be populated by an ERP script, and it can display all the locations where that bike may be, it is up to the planner to update it on a weekly base so that major disruptions are prevented (T2.3).

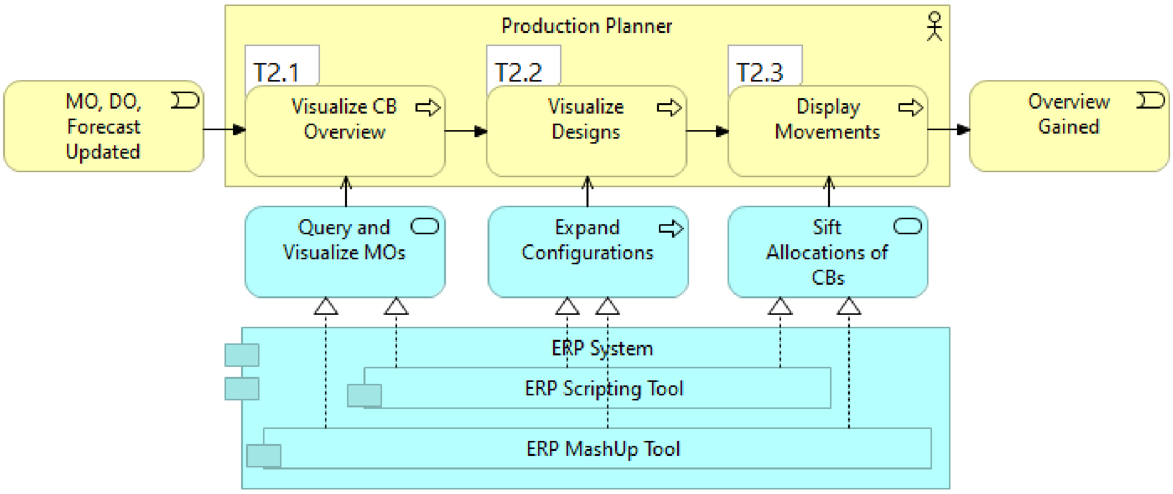

Figure 12 Target Update Excel

5.2.3 To-Be Transport Tasks

Finally, to ameliorate "Transport Tasks", it is desirable to integrate the ERP with external software, automate long tasks and centralize transportation data in a repository. The latter could result in a CS decrease thanks to the reduction of user involvement, while the former will increase PF by enhancing automation. Besides, RE ought to increase because a new repository facilitates caching and redundancy. At first, an ERP Mashup is created which will be populated with the custom bikes to be delivered to painters and those to be collected. In addition, this screen has a "Start" button. Also, in the firm online business to business (BtoB) application, a section must be opened for communication with painters. On a weekly basis, colourers must update what custom bikes can be picked up on which day, and what availability they have for receiving work. In this same platform, painters will be informed about what Bianchi plans to collect, what they will be delivered and when these operations are scheduled. Lastly, an external database must be created with the fleet capacities and painter-related information such as distances, identities, and colours they can tint. This same repository will also store the firm's transportation schedule and the painter's availabilities.

Before explaining the workflow in detail, some instances have been omitted from the model in figure 13 for clarity purposed. Firstly, all the business activities are assigned to production planners. Secondly, the ERP Mashup tool does not only realize the "Inform Actor" process, but it supports all the business layer and the application process "Ask for Variations ". Plus, the ERP send and receive application plays a role whenever the ERP is outputting or intaking information. Lastly, services between software and processes are neglected in the model, but the subsequent section pays careful attention to their explanation.

In practice, the process begins when a production planner opens the new mashup for the first time in a week and presses the "start button". At this point, multiple applications concur to supply a computational software, such as MATLAB or Python, with the information needed to run a transportation-scheduling model. Firstly, an ERP script enquires the enterprise resource planning system database for the list of custom bikes to process, and it clusters them according to the set of subcontractors who can hue their colours. Next, it triggers the external database to share the painters' distances, identities, availabilities for shipping and timing for collection to the computational software (T3.1). At the end of this initialization phase, the external database feeds also information about the vehicle fleets - such as capacities, and the computational software solves the multivehicle routing problem (MVRP) according to some optimization functions and solution algorithm (T3.2) (Toth & Vigo, 2002). It is important to notice that this problem relates to external logistics back and toward painter sites. Internal transportation is not concerned in this procedure as it is the Inventory Management Function responsibility. The generation of this model is out of the scope of this research, and it is left as an opportunity for further investigations. Nevertheless, the resulting transportation schedule ought to be uploaded in the external database, which shares it with the web BtoB and the ERP Mashup (T3.3). In fact, the former will enable the firm's partners to visualize it, whereas the latter allows the company internal actors to view it easily.

If this step is over, and if the mashup screen is opened again within the same week, the ERP script will enquire about variations to the schedule by means of an input table. If this is the case, the MVRP ought to be partially solved again, given the constraints imposed by the changes, and the schedule should be updated in the external database, in the ERP mashup and, in the BtoB software. It is important to encompass this step as operational mistakes might invalidate the plan, while a secondary local optimization could give reasonable solution despite their suboptimality – here it is assumed that only a local optimization could be performed for the model might be too large to be solved anew in a matter of minutes (Gnecco & Sanguineti, 2009) (T3.4). Then, the ERP should read the information on the database and all the material the movement of which is planned for the present day should be allocated by means of the appropriate APIs (T3.5). As soon as the allocations are performed, the system should command to print the corresponding withdrawal lists, the transportation notes and the configurations to the printer web controls (T3.6). However, it was a whim of the production planner to decide when this action should be carried out, because he may be off desk sometimes, and if papers were printed then, the legally binding documentation may be lost. In the end, unless it is Sunday, the user is given the opportunity to reopen the mashup and iterate the process.

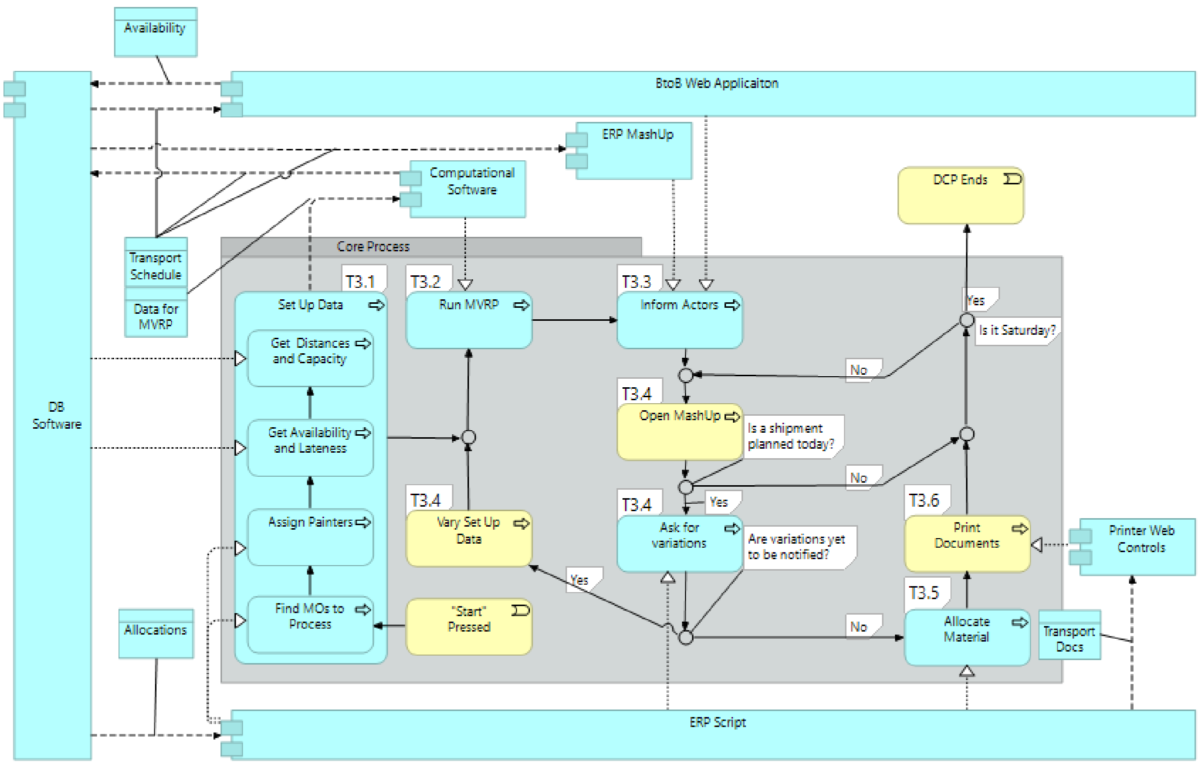

Figure 13 Target Transportation Tasks

5.2.4 Gap Analysis

With regard to "Update MOs and DOs", this process increases performance by 150%, but it experiences the largest drop in resilience. This means that its tasks have an average rank of 6,5 out of

7 in the DYNAMO automation hierarchy, which is 153% higher than the 2,6 assigned in table 13 to "Update MOs and DOs" baseline (Granell et al., 2007). This score is reasonable because, in most of the tasks, all the information is handled by the technology with no user involvement, which results in a score of 7. Moreover, if this is not the case, the technology directs the user to the best course of action, entailing a score of 5. For instance, T1.1 is completely automated, whereas T1.5 requires user action. However, data on the output screen is displayed so that its extraction is facilitated. Also, this process attains the lowest resilience of the three because out of the infrastructures which could accommodate a resilient installation, only 36% is currently presenting one. As of modifiability, the interventions on the ERP are such that out of 5, this architecture mean modifiability score is 2,89 according to the methodology of section 3.2.3. Finally, a cost of 8 indicates that the complexity of the architecture entails the cooperation of at least 8 pieces of software to realize the process. More explanations for these scores are provided in section E.1 to E.4.

Performance	Cost	Modifiability	Resilience	Expected Duration
6,5 150% growth	8 60% decrease	2,89 3,7% decrease	36% 51% decrease	T1.1-T1.5 78-89

Table 17 Score Report of Target Update Manufacturing and Distribution Orders

In terms of target "Update Excel" scores, this architecture presents the largest improvements and grades for some indicators. For example, its performance increase is the highest among the target architectures. At the same time, its cost, and its resilience are pareto optimal, meaning that they are either the best or as high as the best among the other target architectures (Censor, 1977). On the other side, a modifiability of 3 is the worst score of all the architectures. This means that, on a scale from 1 to 5 – with 1 being the best and 5 the worse, the ERP system has been modified so much that on average there will be a difficulty of 3 to implement new variations. In practice, this result was obtained by applying equation 3 on the raw data collected in section E.3 with regard to this architecture. On the contrary, a resilience of 67% means that robust initiatives are planned in roughly two thirds of the areas where either redundancy for backup, data caching or input vetting could be implemented. In particular, the first two are programmed wherever possible, whereas the latter is to be realized nowhere. In fact, the visualize MOs service can be achieved by the mashup logics themselves, and the same holds for the configuration expansion. However, in one case, also some normal bikes would be extracted, in the other, the expansion would be less flexible to human mistakes; nonetheless, redundancy is implemented. Then, the CBs shape and location can be visualized as they used to in the baseline process, thus caching holds. Finally, no impute is checked for maliciousness in the mashup itself. Therefore, despite the ERP vets its users upon access, the local page does not. A full discussion of these plans can be found in section E.4.

Performance	Cost	Modifiability	Resilience	Expected Duration
6,3 165% growth	8 58% decrease	3 50% growth	67% 5% decrease	T.2.1-T.2.3 44-55

Table 18 Score Report of Target Update Excel

Besides, "Transport Tasks" process is the only one which manages to increase resilience, but it has the lowest drop in cost in the set. In other words, resilience increased by 25% because the baseline had four areas where input vetting could have been applied: the excel inputs for CBs, the mails, the ERP material planning mask, and the online repository, and none of them had this robust feature. On the contrary, this target architecture accommodates input vetting only when varying the MVRP data and when printing documents, for these are the only human request contributions, and since a malicious print would be noticed by the staff immediately, the latter is vetted. Thus, applying equation 4 on the raw data collected in appendix E.4 with regard to this process, and computing the variations, yields an increase of 25% in resilience. On the other hand, the slight decrease in cost is justified by the idea behind this architecture. It was said that the purpose of this reengineering procedure what that of integrating the ERP with external software to automate manual processes. If cost is computed as the number of application instances which must interact to execute the process, and the set of operating systems is augmented, it is reasonable that cost will increase as well. In particular, although the excel sheet is removed from the architecture, the information storages, and transitions among external database, BtoB application, ERP script, ERP mashup, and computational software make the number of inputs, outputs, inner databases, and queries explode.

Performance	**Cost**	**Modifiability**	**Resilience**	**Expected Duration**
6,3 133% growth	24 4% decrease	2,82 41% growth	50% 25% increase	T3.1-T3.6 53-76

Table 19 Score Report of Target Transportation Tasks

As of closing the gap with reality, “Update MOs and DOs”, “Update Excel”, and “Transport Tasks” have raised their PF by 150%, 165%, and 133% respectively in comparison with that of their baseline counterparts. Hence, DR could drop as less as 0,32% for each 1% increase in PF and the research problem would still be solved. In fact, if this was the case, the new EDCP activities throughput time would be about 48,5%, 53,3%, and 43% lower than their baseline, with corresponding analytical values between 78 and 89, 44 and 55, 53 and 76 seconds per bike respectively as reported in table 17, 18, and 19. Hence, resulting in more than 43% throughput time reduction in total.

Finally, some technical complications ought to be clarified. Although it is desirable to have the MVRP solved by a specialized software, it may be very difficult to communicate any information from the ERP script to the computational system because such instruments usually do not have internalized communication channels. A solution to this matter would be that of implementing the optimization algorithm directly in the ERP scripting tool. However, in this case the scripting mask ought to be open in the background to compile and little is known about the effects that this would have on the overall ERP usability. For example, the calculations could be extensive and intense enough to make the system slow for long periods. Zooming back to the reengineered processes, considering their classification and the importance of the objectives given in table 8, the implementation order suggested would be “Update MOs and DOs”, followed by “Update Excel” and then “Transport Tasks”. In fact, PF is worth 53,5% of the selection and target “Update MOs and DOs” scores best in it. Moreover, it ties first for CS, which is the second most important criterion. As of the third most relevant attribute, it is second. All these are solid argument to contend for its priority in an implementation scenario. Then, to-be “Update Excel” ties first for CS, which counts for 26,75% of the selection, and it is the best for RE, and MD, although together they only amount to 19,8% of the decision. Finally, although “Transport Tasks” has good RE, and PF, its burdensome CS restrains its attractiveness. However, as Heerkens and Van Winden (2021, p. 91) suggest, the final decision should be delegated to the problem owner, and the subsequent section elaborates on how the decision maker made up his mind.

6. Solution Selection

So far, the solution objectives were identified, and their corresponding practical counterparts were derived. Then, the current process was mapped and analysed while new architectures were developed to improve it. The reader is presented the selection of the processes as resulting from the application of Analytical Hierarchy Process as to answer RQ 6 (Winston & Goldberg, 2004, p. 778). Moreover, a sensitivity analysis is performed on the importance of some criteria. Unlike most authors, this paper shows an approach to perform this task by means of mathematical analysis (Chang et al., 2007). Two reasons bring the author to perform a solution selection process which entails the decision maker. Firstly, the solution development logic aimed at optimizing indicators of the design objectives, thus, any recommendation stemming from them could be inherently imprecise. Secondly, in an environment with scarce resources, it is important to rank and prioritize which solution to implement first, and AHP fits this need properly (Vaidya & Kumar, 2006).

6.1 Analytical Hierarchy Process

Table 20 reports the results of AHP, in the leftmost column, T1, T2, and T3 represent the target architectures of "Update MOs and DOs", "Update Excel" and "Transportation Tasks" respectively. They are sorted in descending order of importance and the bottom row represents the weight of each criterion. Instead of reporting all the passages followed to attain this results, appendix F displays the user inputs and the intermediate computations. As the reader can see, T1 is the winner in value, then T3 and finally T2. This value order corresponds with the sequence in which the decision maker would prefer to implement them. Moreover, the consistency ration for this application attained 5,61%. Note that the background colours of the options on the leftmost column of table 20 is the same in which their score is portrayed in figure 14.

Score	Perfromance	Cost	Modifiability	Resilience	Value
T1	0,26	0,70	0,52	0,68	2,91
T2	0,06	0,23	0,33	0,20	0,97
T3	0,68	0,07	0,14	0,12	2,67
Importance	3,50	1,75	0,67	0,63	

Table 20 Summary of AHP Results

The choice of T1 as the most desirable architecture is reasonable. Despite it scores second in performance with a value almost one third of that of T3, it largely dominates all the other solutions in implementation cost, modifiability, and resilience. It is noticeable that none of these results align with the analytical grades of section 5.2.1 to 5.2.3 as for instance, T2 was deemed to outperform T1 in terms of cost, with a score of 8 against 10. Although possible explanations abound, one is particularly probable. It is possible that, in his valuation of the scores, the decision maker considered different factors than those used in the operationalizations of sections 3.2.1 to 3.2.4. On its turn, this could be due to the fact that the quantifications were not thoroughly comprehensive, and because the decision maker background concerns production techniques rather than IT systems.

6.2 AHP Sensitivity Analysis

Moreover, since demand for custom bikes is growing, it is reasonable to believe that over time the importance of cost will decrease. In fact, the higher the number of orders, the larger the congestion due to the slow DCP, the more a decision maker will be willing to spend in order to solve it. At the same time, the more time passes, the more the problem owner may deem modifiability relevant, as organizational processes are in continuous change (Kittinger et al., 1997). Hence, over time, the DCP workflow will have deviated from the current one. Hence, even if the architectures had not been implemented yet, in the future, the decision maker would prefer them to be more modifiable, so that they could still be realized. For these motives, it is relevant to investigate how preference changes when the weight of cost decreases, and that of modifiability grows. If s_{ij} is the score of alternative $i = 1,2,3$ in criterion $j = 1,2,3,4$, where alternatives are respectively T1, T2, T3 and the criteria are respectively performance, cost, modifiability, and resilience, and w_j is the importance of attribute j for each j, then, $v_i = \sum_j w_j * s_{ij}$ is the value of alternative i and all these values can be retrieved from table 20. Let $v_i(x, y)$ be the value of alternative i when the importance of cost changes by x units and that of modifiability by y, then it can be argued that equation 5 holds because:

$$v_i(x, y) = w_1 * s_{i1} + (w_2 + x) * s_{i2} + (w_3 + y) * s_{i3} + w_4 * s_{i4} \qquad \forall i$$

$$v_i(x, y) = \sum_j w_j * s_{ij} + s_{i2}x + s_{i3}y \qquad \forall i$$

$$v_i(x, y) = v_i + s_{i2}x + s_{i3}y, \qquad \forall i \qquad \textit{Eq. 5}$$

Then, given options $k, l \in \{1,2,3\}$ to identify when k is preferable to l is to find all the couples $(x, y) \in \mathbb{R}$ such that $v_k(x, y) > v_l(x, y)$, which is to say that all the real (x, y) that satisfy equation 6 must be found.

$$y \geq \left(\frac{v_l - v_k}{s_{k3} - s_{l3}}\right) + \left(\frac{s_{l2} - s_{k2}}{s_{k3} - s_{l3}}\right) x \qquad \forall k, l \qquad \textit{Eq. 6}$$

However, for practicality purposes, the present analysis is restrained to investigate x and y in two limited domains which are $x \in [-1{,}75; 0]$ and $y \in [0; 1{,}34]$. Then, the application of equation 6 under these constraints yields that T2 is never preferred within these boundaries, whereas T1 is the most desirable only for $y > -0{,}63 - 1{,}66x$, elsewhere, T3 is the most preferable. The left-hand side of figure 14 portrays the value of options T1, T2 and T3 against the total importance of modifiability and cost rather than their variations, whereas the right-hand side splits the plane in areas and within each only the colour of the most preferred solution is given. Note that although even a slight change in modifiability would compromise the optimality of T1, cost should vary significantly for T1 not to be the most desirable anymore. Thus, it is reasonable to proceed with an implementation plan for this option, and the subsequent section shall address this matter.

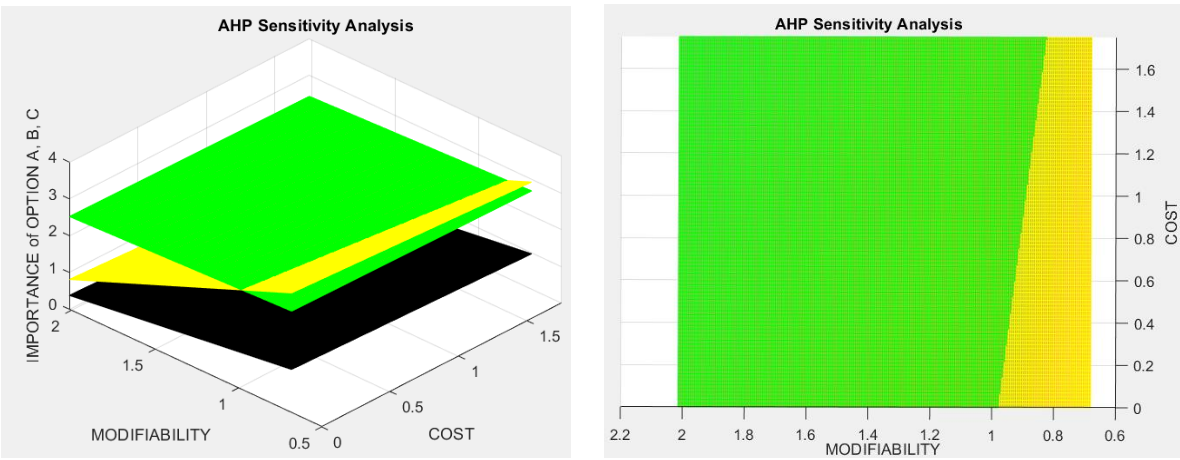

Figure 14 Sensitivity Analysis of AHP Results

7. Demonstration

Henceforth, the reader is presented how RQ 7 is tackled by means of a technical implementation and a social one. On the one side, the practical steps which are to be carried out are analysed. On the other hand, how the company personnel should be managed to support the change is described. Also, this section executes the demonstration phase of DSRM.

7.1 Technical Implementation

Since “Update Manufacturing and Distribution Orders” is the winner, the subsequent section aims to explain how to technologically implement it. The development methodology is based on the Agile Method (Beck et al., 2001). Within this framework, the logic of a minimum viable product (MVP) is explained, and a visual mock-up is presented (Ries, 2009).

To start with, there may exist multiple minimum viable products for the final artefact described in figure 11, but in consultation with Bianchi’s IT department, figures 15 to 17 report one which seems to balance ease of implementation with performance benefits. Figure 15 captures how “Update MOs and DOs” would vary under this intervention and overall, the idea concerns automating the creation of DO and the MO by means of the ERP scripting tool. Then, figure 16 represents what logic should be coded in the named environment to serve this purpose. Since the scope shifts from EA to software development here, the language moves from ArchiMate to EPC (Krylov et al., 2008). In addition, figure 16 shows how the interfaces would look like when this first creation step is finalized.

In detail, the script should be loaded when the planner opens the ERP forecast visualizer to look for a free slot for the custom bike at hand. When compiled, it should create a button with its description as highlighted in the red square at figure 17 left hand side. The button should be coded as explained in figure 16, so that upon pressing, it opens an auxiliary page. Since this step is performed when the planner has retrieved the data of the identified empty forecast slot, this mask ought to have entries for each piece of information requisite to run the create MO and DO APIs. Moreover, according to what control is activated, the supplementary mask should trigger different actions. Although the right-hand side of figure 17 shows multiple buttons on the newly created page, only two of them are strictly necessary to be regulated.

Firstly, the V-shaped button should evaluate which entries have been filled, and according to this, it should run the create MO or the create DO API, or none, or both. If the application program interfaces run properly, this should be notified in the ERP message field at the bottom of the page – note that this area is not represented on the left of figure 17 as it only appears when compiled. Alternatively, if errors occur, their description should be reported in that same area. In both cases, the routine should allow to trigger more commands. In the very minimum viable product, the arrowed button is the only remaining control to enact. Upon pressing it, the auxiliary window shall be closed, and the user ought to be brough back to the screen on the left of figure 17.

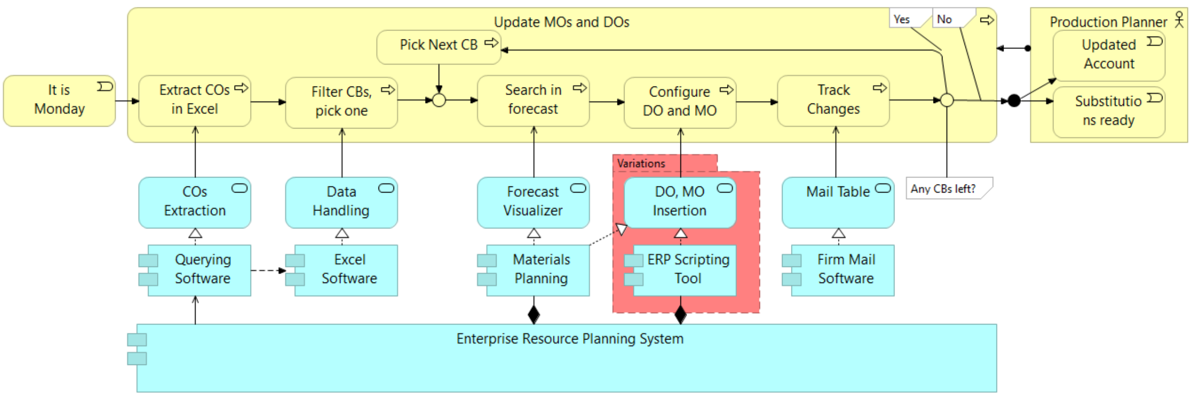

Figure 15 Update MOs and DOs process when the minimum viable product is implemented

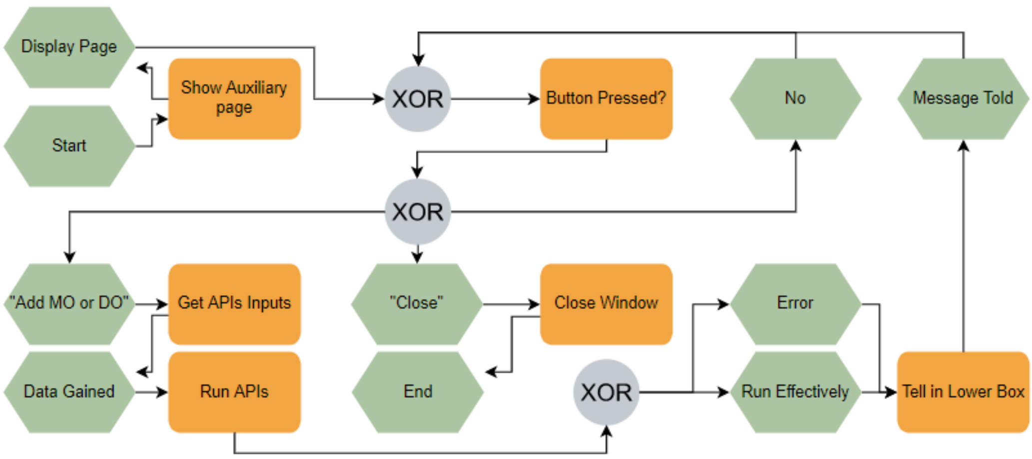

Figure 16 Forecast Visualizer Button Logic in the Minimum Viable Product

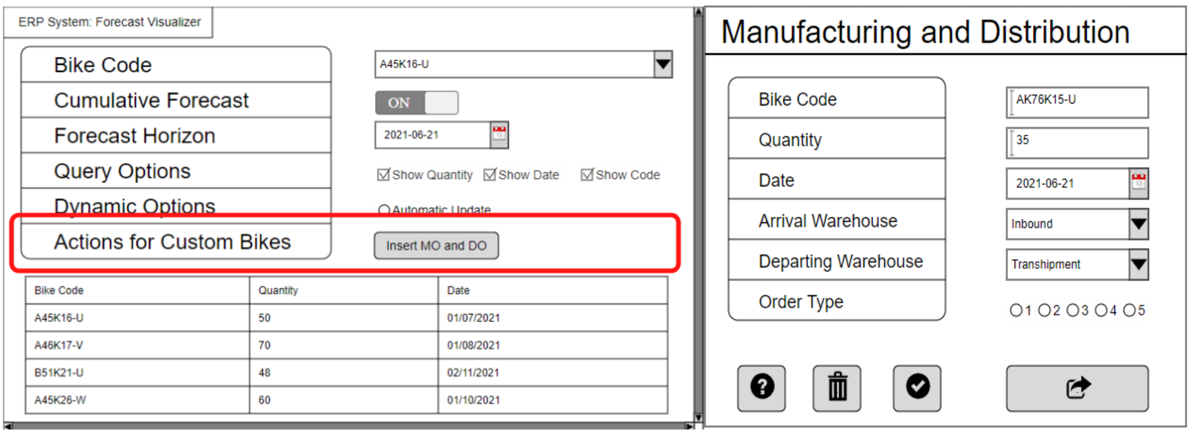

Figure 17 Forecast Visualizer Mask in the Minimum Viable Product, and page triggered by the new button

Several strategies exist to implement the architecture of figure 11 starting from this minimum viable product. However, knowledge of the optimal one is left for further research. On the contrary, here, the reader is presented a reasonable path to succeed in this endeavour which consists of two further steps. The tactic to follow would be that of improving the software iteratively, until the final artefact coincides with the target architecture (Basil & Turner, 1975). Firstly, the current product should be complemented with the ability of searching for an empty forecast slot when input with a CO line. As of the back end, unfortunately, no API seems to be capable of accomplishing this step, but an SQL query can be built in the scripting tool instead. In regard of the front-end, the auxiliary page should accommodate the unique ID of an order row and it should return the specifications of the chosen forecast slot too. The second customization would request the front end to be completely erased and the ability to read the demand-insertion mask should be programmed by mans of scripted rules. Then, the same logic employed so far could be fed with the unique order lines acquired from the screen, and the architecture would be almost finished, save the loops implementation.

In terms of costs and benefits, the three steps to realize the target architecture require different efforts and yield dissimilar benefits. In consultation with Bianchi's IT department, it was agreed that the realization of the MVP was fairly easy, and if the to-be process was not to be fully implemented, it would be cheapest to have this step carried out by the firm IT department itself. However, its benefits are marginal, as it only shortens the creation of MOs and DOs. Vice versa, if the firm aims to implement the entire architecture, the greatest benefits are probably gained in the second implementation phase. In fact, this step would abridge the search in forecast, which is a rather extensive activity. Nevertheless, this passage is definitely time expensive to implement because the scripting software is not directly structured to accommodate SQL queries. Hence, they must be encapsulated in the local programming language, and this requires abundant expertise. Thus, if the project is to be implemented thoroughly, it would be advisable to outsource its realization. Finally, the last step would yield marginal aids and its implementation effort is complex to conjecture. Although curtailing the front-end reduces completion time, there is some uncertainty about how to read information from a custom-made table. Hence, not only an external provider should take care of this, but the cost of such operation is vague at this point in time. Thus, the suggestion would be to outsource the implementation and have it performed until the last step. Then, evaluate its cost and decide whether to finalize it.

7.2 Social Implementation

Next, as Heerkens and Van Winden (2021, p. 104) suggest, there are various factors to consider when dealing with change management. For brevity's sake, the analysis is carried out on three layers. Firstly, how to control change and communication is decided. Then, whether the migration should be bottom-up or top-down is settled and finally, an appropriate involvement plan is created for the workforce.

Firstly, as mentioned already, if the entire project is implemented, then it is reasonable to have it carried out by external specialized workers, and Bianchi ought to focus on communication with them mainly. As of the structure of discussions, the production manager should be involved because he has essential knowledge of the planning processes. Moreover, the IT and the commercial directors should join the debate too as the former has critical information about the enterprise architecture, while the latter is in the position to make financial decisions. All together, they should form a managerial team which the IT consultants can interact with. At the same time, the planners should be included in the project as they are the final users. In fact, they ought to be involved in testing the applications and they should be open to share suggestions.

Hence, three communication channels should exist. Firstly, the cheapest way for the management to communicate with the specialists is by means of a combination of real-life meetings, and telematic discussions. This method is not necessarily the most effective, however, the company seems accustomed to iterating this practice, and they appreciate it. As of feedback from planners to the consultants, analogous considerations hold. Nevertheless, package releases ought to be coupled either by a real-life explanation, or by an online user tutorial. The last connection to treat is that between the management and the planners. Little information ought to be shared on this level, such as launch dates and major software drawbacks. Since most of the workers attend their job in person, such discussions can be organized in periodical meetings.

This arrangement of roles has implications on both the migration methodology and the personnel involvement plan. As of the former, the implementation is to be directed in a top-down fashion mainly. In fact, architectural models exist, thus the project reduces to coordinating their implementation as explained above. However, this realization plan has a bottom-up component which concerns the feedback and testing done by the production planners. This last component is particularly strategic in terms of cultural shift. In fact, Heerkens and Van Winden (2021, p. 104) suggest that if the workforce is involved in the technological shift, it will be accepted and integrated more easily. Therefore, in the hope of facilitating the transition among systems, final users' feedback is not only to be listened to, but also to be integrated in the system.

To conclude, in the beginning of section 5, it was mentioned that all the new designs were validated for feasibility of realization. This is the case for this three-step implementation approach too. Also, the social implementation is to be led by the management and supported by the staff, while communication must be threefold, among personnel, directors, and external IT specialists.

8. Conclusion

As follows the paper is concluded in a threefold fashion. Firstly, the limitations of this research are outlined. Secondly, the author opinion on what the firm ought to do is uttered and eventually, the findings are summarized.

8.1 Summary of Findings

First thing first, the research results are synthetized, and the paper conclusion is given. To accomplish this goal, the subsequent paragraphs are structured to summarize and answer the various methodological research steps. In fact, the investigation was carried out according to Design Science Research Methodology, and its steps were integrated with the blueprints of Managerial Problem-Solving Methodology, Managerial Research Question Hierarchy and Business Analysis Body of Knowledge.

The first DSRM phase concerns identifying the problem and motivating. This step was executed according to MPSM stage 1 and 2, namely “Problem Clustering” and “Problem Analysis” (Heerkens and Van Winden, 2021, p. 39). In fact, the project was offered by Bianchi’s production department with the goal of subsiding operational distress, and the cause to this superficial symptom was to be found. To this purpose, the production planners were interviewed and the problem they mentioned were mapped with causality links. Out of them, the slow process of data handling for customizable bicycles’ production (DCP) was agreed to be the most relevant because, although employees can somewhat contain the other matters by themselves, they can by no means shorten the DCP operations as they lack managerial proficiencies. Next, a literature study was performed to identify common causes to inefficient IT processes in similar firms, and Bianchi’s management board was questioned which of them applied in this case. Eventually, out of the set of motives to the slow DCP, the ERP configuration was decided to be the most important because its inadequacy implies the need for much manual work in the process realization.

Next, after some data gathering, Bianchi’s core problem was operationalized as “Over the last year, the planning department of E. Bianchi spent on average 15,5 hours a week to enact the DCP, whereas this value ought to be 9 hours”, and the consequent knowledge problem was “How can Bianchi vary the ERP configuration to shorten the DCP throughput time by 43%?”. At this point the research questions were derived from the knowledge problem according to the Managerial Research Question Hierarchy, and they aimed at completing the second, third and fourth phases of DSRM. Namely, “Define Objectives of a Solution”, “Design and Development” and “Demonstration”. But given that most of the research questions are approached from the perspective of business process modelling, a literature study preceded the research execution to investigate which languages could be used to notate a workflow, along with their ability to capture the information and process dynamics. According to this analysis, Business Process Management Notation is the second best at capturing processual flows, and thanks to its numerous extensions, it is the best at incorporating information. Nevertheless, ArchiMate presents some unique features which make it the right language for this study. In fact, it is the only one which enables the representation of business and application layers at once, which is essential for an architectural study of Bianchi’s ERP-based processes.

Once the dispute about modelling language is settled, the DSRM is restarted at the “Design Objective of a Solution” stage. As suggested by MPSM phase 5, interviews were performed to identify which attributes would have made a reconfigured ERP architecture more desirable, and the production manager revealed that performance, implementation cost, ease of modifiability, and resilience were the four most relevant criteria. Then, they were operationalized to guide the technical development of the IT architecture as suggested by BABOK "Requirements Analysis". In particular, the first was tracked by means of a surrogate indictor based on the DYNAMO framework for software automation. Secondly, cost was tracked as a simplification of the Unadjusted Function Points, by counting the number of software components interacting to execute the process. Thirdly, modifiability was monitored as a function of how modified the ERP system had been manipulated, and resilience was intended as the degree to which input vetting, data caching and redundancy were implemented in the architectures.

Afterward, the "Design and Development" phase was carried out. In this case, as prescribed by BABOK's "Gap Analysis", observation and interviews were used to conceptualize the DCP, select which of its activities depended on the ERP and part them into three sub activities, namely, "Update MOs and DOs", "Update Excel", and "Transport Tasks". Each of these was expanded and its application stack was outlined in ArchiMate models, and a first visual inspection revealed that most of the activities were executed by human actors, suggesting a considerable duration. This hypothesis was confirmed when the workflow cycle time was investigated by interviewing the production planners, revealing that the three EDCP macro activities took respectively between 162 and 183, 83 and 104, 125 and 176 seconds per bike to be completed. Next, their performance, cost, modifiability, and resilience were measured by means of the surrogate indicators and this yielded some interesting results. For instance, "Update MOs and DOs" baseline ranks second in each design objective, except for resilience where it ties first with "Update Excel". As of this process, it is the best in terms of cost, modifiability, and resilience, but it ranks last under performance, an opposite pattern is presented by "Transportation Tasks", which rank first in performance but last in all the other criteria. This examination also revealed that cost and modifiability had to be increased for all the workflows, while resilience was to be enhanced only for some. Also, performance has to grow in order to enable the 43% duration reduction.

The second step toward the completion of "Design and Development" entailed the actual redesign of the ERP. In this phase, a methodology was drafted and followed as to ensure that major working bottlenecks were addressed more significantly, that attributes relevance was mirrored in the solutions, and that fixation was prevented (Lu et al., 2017). Then, the ERP instances which could be varied were investigated and it was discovered that the system has a scripting tool capable of customizing internal dynamics, a mashup instrument that can create new windows, and a communication vehicle which enables cooperation with outer software. Thus, according to this development method, the key strategy to innovate "Update MOs and DOs" appeared to be that of automating the production planner tasks into the ERP scripting tool. Likewise, "Update Excel" was improved by programming the excel overview into the ERP mashup and automating the iterative update. Finally, the strategy to ameliorate "Transport Tasks" was funded on the idea of outsourcing time-consuming activities to external software where they could have been automated.

Again, the resulting target architectures were measured in their solution objectives and the results are worth reporting. With regard to "Update MOs and DOs", it ranks second in modifiability and worst in resilience, however, it scores first in performance, and it ties first in cost with "Update Excel". As of this process, it now is the least desirable in terms of performance and modifiability, but it scores first in cost and resilience. Finally, "Transport Tasks" rans first only in modifiability, and it is last for performance and cost. Overall, cost and modifiability were increased. As of performance, it grew by more than 100% in each model. The growth was such that even if duration dropped as less as 0,32% by each 1% increase in performance, the core problem would still be solved. In light of this analysis, the suggested implementation order would be “Update MOs and DOs”, “Update Excel”, and “Transport Tasks”. Nevertheless, the final decision must be taken by the problem owner.

To conclude the “Design and Development” phase, analytical hierarchy process was performed on the problem owner to select in what order the reengineered architecture were to be implemented. It results that “Update MOs and DOs” was the most urgent one, closely followed by “Transport Tasks”. However, as time passes, modifiability is expected to grow in importance and cost to decrease. Hence, this scenario was investigated by means of a sensitivity analysis, and it was discovered that if x is the units by which the importance of cost varies and y is the change in that of modifiability, “Update MOs and DOs” remains the most desirable solution only as long as $y > -0{,}63 - 1{,}66x$. Moreover, within a variation of 100% in both the parameters, “Update Excel” is never the preferred option.

In the light of this situation, the “Demonstration” stage was performed with “Update MOs and DOs” as subject. In this regard, the technical implementation was split into three steps according to the Agile Development Methodology. First, the insertion of MOs and DOs should have been executed on the forecast visualizer screen. Then, the ability to gain an empty forecast slot autonomously should have been coded in the tool, and finally, the logic should have been customized to trigger automatically when a new customer order arrives. Meanwhile, the social dimension of the innovation should be handled according to the principles of change management. In this regard, communication should be threefold. The management should outsource the implementation to an external subcontractor and take decisions with them. At the same time, production planners should test product iterations and give feedback for improvements. Also, planners should update the management for major problems with the new instruments. This top-down and bottom-up involvement ensures a comprehensive view of the new technology and increases its acceptability.

8.2 Recommendations

After the outline of the research activities and findings, recommendations about what to do are to be considered, and in particular, a clear decision is to be taken: internalize some more software development knowledge or not.

Firstly, it is wise to implement the to-be “Update MOs and DOs” according to the methodology given in section 6.2. However, this would probably not suffice to attain a 43% reduction in DCP duration. To accomplish this, one should approach the implementation of the target “Transport Tasks”. Despite being a complex architecture, this system would probably enable to shorten cycle time radically. Moreover, it would increase the performance of practical processes as well, because following an up-to date optimal transport schedule would increase efficiency and reduce overall operational costs. Due to its technical complexity, it would be unwise to have this system implemented internally, as this would call for considerable investments in personnel formation. If the realization of “Update MOs and DOs” will be subcontracted as suggested in section 6.1, it would be intelligent to let the same consultant take on the project of implementing “Transport Tasks” too, as its experience with the enterprise architectures would speed up the process. In regard of “Update Excel” implementation, not only it is to be left last, but according to what I experienced, it could be easy enough to be performed by the internal resources too. Therefore, although the ERP development skills needed to implement the first two processes are too advanced for a strategic internalization, the firm would benefit from improving its employee’s software development abilities to some extent. In the short term, this could enable to program the target “Update Excel” without outsourcing it, whereas in the long term, it would be tactical for trouble shooting and minor software patching.

8.3 Limitations and Opportunities for Further Research

As follows, research opportunities are treated. Firstly, the target architecture of "Transport Tasks" entails scheduling the logistical operations. The development of models suitable for the given problem is left for further research. Also, refining "Update MOs and DOs" implementation strategy is another opportunity because the current one aims to be feasible rather than optimal. In addition, another research possibility is designing a realization plan for "Transport Tasks", and for "Update Excel".

As of limitations, although necessary for practicality purposes, the one-dimensional operationalization of indicators is a major weakness. It might not only have led to misjudgements with regard to workflows performance, cost, modifiability, resilience, and duration, but since the reengineering effort aimed at increasing these measurements scores, it might have misled it as well. This controversy might explain why there is no proportionality between the structural scores computed for the processes and those judged by the decision maker during AHP.

Secondly, the problem operationalization ignores overhead costs, biasing the size of the problem, and the target architectures solve the matter only if duration drops by at least by 0,32% when performance grows by 1%. Another limitation is that only the ERP extensions which the firm owned were considered in the solution generation. Also, the construction of the baseline processes draws on interviews and testing in the ERP simulation environment. Nonetheless, there may be some variations between it and the true environment, thus corrupting the as-is workflows reliability. The final pitfall concerns the solution selection phase. In fact, it is possible that the weights were skewed toward performance and financial measures because production management perspective of the problem owner.

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Appendix A: Identifying the Core Problem

Appendix A.1: Cleaned List of Action Problems

As follows the polished list of identified action problems is reported, no specific order is given. The same issues are structured in figure 3.

Overloaded planning department
Employees handle data inefficiently
Employees cooperate inefficiently
Many unexperienced workers
Inappropriate division of labour
Time consuming planning
Delays due to process errors
Lack of error detection methods
Error handling is time consuming
Lack of error prevention methods
Slow planning of customizable bikes

Table 21 Polished list of action problems

Appendix A.2: Overview of Stakeholders

The organigram in figure 5 represents internal and external stakeholders to the production division of the planning function. For privacy purposes, this exhibit does not display any name and includes only those roles which are either victims of the slow DCP or capable of helping me to research solutions. Note that on the vertical direction a connection line indicates hierarchical dependency in the firm responsibility system. In other words, the sales accountant is led by the commercial manager while the planners and the warehousemen respond to the production manager.

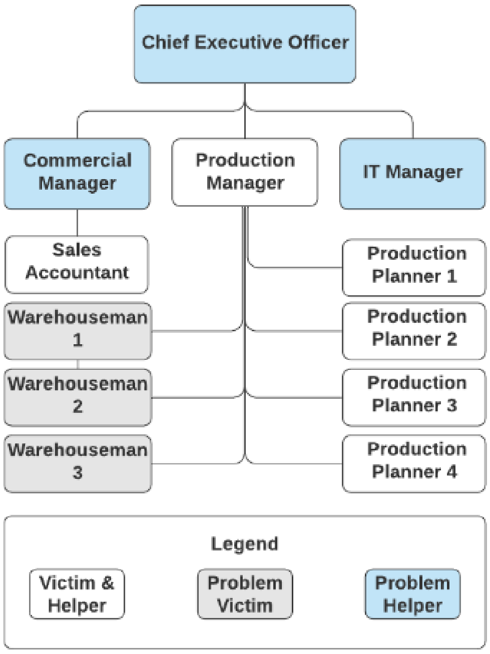

Figure 18 Organigram of relevant stakeholders

Appendix A.3: Derivation of causes to the slow DCP

After having identified problems on a high level of abstraction, the slow DCP was agreed to be the most prominent. Given the low response of the planners on its causes, literature was explored to find potential motives to it. As of the search strategy, the knowledge problem used was: “What factors affect the efficiency of a process supported by information systems in a medium industry?”. In regard of inclusion and exclusion criteria, articles in press or published before the 2000 were ignored because they are either uncertified or published before the raise of Business Process Management as a formalized science. Considering journals and books as the only accepted source types was another technique to ensure reliability of findings. Moreover, only engineering, business, management, and decision science were applied as relevant subjects because of their pertinency. Solely Scopus was used as database because of its broadness and figure 6 represents the initial search matrix.

Key Concept	Synonym	Narrower	Broader
Factor	Aspect, ingredient	Thing, influence, fact	Cause, element, variable
Efficiency	Capability, performance, productivity	Profitability, economy, cost-efficacy	industriousness
Business	Enterprise, company, firm, organization	Department, function, actors	Industry, work, corporation
Process	Procedure, method, operation, routine, scheme, workflow	Action, task, step, activity	Technique, methodology
Information System	Data system, Information management	Data network, informatics	Computer system, information technology

Table 22 Concept matrix for problem analysis

From time to time, these terms had to be recombined and united with new ones, such as “survey”, “theory” and “mediation”, to skirt the scope of the results. Hence, the reader is reported the searched strings which produced relevant articles in table 12. It is worth noting that not all the significant findings were identified immediately in the main results. Three adequate papers were found by forward and backward snowballing on other relevant ones and on relevant authors. For instance, Tatoglu was identified as a key writer in this field and further investigations were performed on his works to identify relevant ones which he had co-authored or published.

Database	Search String	Results	Relevant
Scopus	((factors) and (performance or capabilit*) and (organization* or business) and (process) and (IT) and (theor*) and (survey) and (independent or dependent or mediated or variable))	58	3
Scopus	((factor or measure) and (impact) and (performance or success) and (business) and (process) and (empirical) and (conceptualization))	15	2
Scopus	(impact* or practices) and ("operational performance") and (management) and ("information systems") (empirical or theory or survey) and (mediating or influenc*)	8	1

Table 23 Search log for problem analysis

Consequently, the factors affecting performance of a business process are synthetised in table 13 whereas figure 7 clusters them in a framework explaining their causal relationship with respect to the dependent variable.

Variable	Meaning
Process Automation	Degree to which software applications orchestrate and carry out process operational tasks. (Belekoukias et al., 2014)
Human and Administrative Capabilities	Skills of operators using the system and managerial ability to shape the information technology to pursue strategic goals (Aydiner et al., 2019).
Process Streamlinization	Degree to which the process has been reduced to its essential activities and follows comprehensive protocols. (Munsterman et al., 2010; Belekoukias et al., 2014).
IT Capabilities	Degree to which the functionalities and integration of management software foster process execution (Chen et al., 2014; Tatoglu et al., 2015).
Business Environment	Dynamism, local workforce education, workforce innovation resistance and market hostility (Chen et al., 2014).
Adoption of Business Analytics	Use of information technology to store and analyse data with the purpose of transforming it into knowledge to drive the business (Aydiner et al., 2018).

Table 24 Model concepts definition according to this paper.

In the following figure, squares represent variables and arrows are causality dependencies. The reference inscribed in each construct indicates the article corroborating the outgoing arc. It should be explained however, that speed is a relevant part of each article’s operationalization of performance. Therefore, the explanations hold even if the dependent variable is reduced to process velocity.

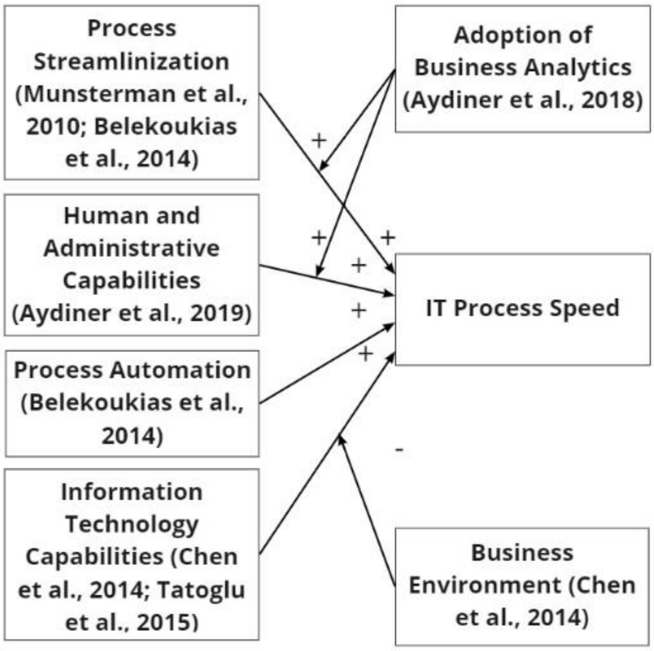

Figure 19 Literature factors affecting the performance of an IT business process.

Next to the literature search, field exploratory interviews were performed to evaluate which factors were relevant barriers to the performance of the DCP according to the helpers' opinion. The interviews revealed that human capabilities were not important contributor to performance in this case, and that adoption of business analytics could be disregarded as well as business environmental factors. However, some mentioned that the problem originated because of low abilities of past administrations, but since these managers are retired now, this issue is intractable. In addition to that, multiple of the matters uttered can be categorized as lack of automation or improper IT capabilities. Hence, under "augmented problem cluster", Figure 2 displays the causes for the slow DCP as underscored by the employees.

Appendix B: Research Design

The upcoming table displays s research questions key concepts and their definition in accordance with the theoretical perspective. Overall, variables which repeat among questions, or which were outlined in the knowledge problem are not defined twice and they take on the same meaning in every research question if they repeat. However, ERP configuration is refined although it was explained in the theoretical framework, to align it with the theoretical perspective. RQ are grouped by the academic framework within which they are answered. Thus, they are not displayed in numeric order.

Research Question	Perspective	Key Concepts	Definition
2	Theoretical, Utility Theory (Broome, 1991)	Criteria	Attribute against which the attractiveness of a solution is decided by the decision maker (Heerkens and Van Winden, 2021, p. 77)
		Relevance	Measurement of consumer satisfaction received on the consumption of a good or service (Broome, 1991)

6		Desirability	The appeal of a solution as a function of its score under the decision criteria and the relevance of each selection characteristic (Winston & Goldberg, 2004, p. 778).
1	Disciplinary, Business Process Modelling (Weske, 2007, p. 7)	Modelling Language	Metalanguage providing an abstract execution model for processes based on the finite-state machine concept (Weske, 2007, p. 7)
		Business Workflow	The sequence of steps used to move from the beginning to the end of a working process (Van Der Aalst and Jablonski, 2000)
		Digital Workflow	The identification and documentation of applications customer-supplier relationships about data transmissions (Popa et al., 2009)
		Level of Abstraction	Degree to which process elements are deemed insignificant and thus excluded from the representation (Polyvyanyy et al., 2015)
3		Input and Output data requirements	Minimum completeness, and accuracy of data required by an activity from a completed preceding one (Wong et al., 2006; Weske, 2007, p. 374; Vaziri et al., 2019)
		Activity completion time	Description of the duration of each process task meant serve the final process goal or outcome (Ceci et al., 2014)
4		Bottleneck	Process in a chain of processes that has low capacity and reduces the entire throughput rate of the system (Slack et al, 2010, p. 117)
7		Technical Implementation	The activities that need to be performed, clustered in time, in order to complete the implementation of the found solution (Heerkens and Van Winden, 2021, p. 103)
5	Disciplinary, Database Design (Harrington, 2016, p. 4)	ERP configuration	Ability to natively perform a certain function by changes on the intermediate and lowest optionality levels – that are object and occurrence levels respectively. It may vary the relational data structure in the database, and facilitates variance in its single process instance performance (Soffer et al., 2003)
		ERP Architecture	layout of layers of application deployment between servers and desktops, interfaces, and in particular software objects (Weske, 2007, p. 49).

Table 25 Research concepts and constructs

Finally, in the ensuing table, relevant operationalisations are given and those variables which are not properly quantifiable are categorized according to literature. Again, if a concept or variable appears in more than one research question, and its operationalization is relevant, it is outlined only once under the first RQ in which it shows.

Research Question	Relevant Variable	Operationalization and categorization
1	Workflow	Workflows are explained in modelling languages, which capture activities, actors, and structures on business, application, and technology layers (Josey, 2013, p. 26).
	Level of Abstraction	Levels of abstraction are categorized into strategic, tactical, and operational according to the hierarchy of levels of abstraction (Monsalve et al., 2015).
2	Relevance	Value for each attribute level as resulting from using AHP approach (Winston & Goldberg, 2004, p. 778).
3	Data Completeness	The range of data an activity requires from the former one to function, with their type and values
	Data Accuracy	The degree to which the data transmitted must comply with the ideal one to enable the subsequent operations to fire.
4	Activity completion time	It is the time laps between the activity is set up and its completion, regardless of how many actors interact on it or whether its result is right or wrong (Slack et al, 2010, p. 286).
5	ERP configuration	ERP configurations which are considered in this classification are catalogues, tasks, business processes, chart of characteristic types, enumerator, commands, filters, setting repositories.
	ERP architecture	ERP architectures which are considered in this scope are those of parts and products structures, product variants, master data, and the relational structure of customer order entity (Kurbel, 2016, p. 20-42).
6	Desirability	Degree to which a solution meets the decision criteria weighted by their importance as explained in Analytical Hierarchy Process by Winston and Goldberg (2004, p. 778).
7	Technical Implementation	The technology roadmap symbolizing how to bring about the innovation. It can be bottom up or top-down. Meaning that its execution is on the management or on the workforce. (Heerkens and Van Winden, 2021, p. 104)

Table 26 Overview of research operationalization

Appendix C: Literature Reviews Search Strategy

Appendix C.1: Modelling Languages Search Strategy

To perform the structured literature review, the author integrates the theory provided by his undergraduate courses with the methodology outlined in "How to Perform a Structured Literature Review" (Purssell & McCrae, 2020). This requires a preliminary identification of the knowledge problem, the definition of the search domain, the search strategy, and the findings analysis. As follows, these topics are outlined in appendix B.1 through B.4 respectively. Moreover, the theory integration and synthetization are reported in section 4.1 of the project plan.

Appendix C.1.1: Knowledge Problem

To start with, the knowledge problem is defined as research question one (RQ 1) in table 6 while its main concepts are defined in table 8 and its variables are operationalized in table 9. RQ 1 reads "What languages can be used to model the human and digital workflow of the order management on an operational level of abstraction?". To ensure that the number of key concepts was between 2 and 5, that they did not overlap, and that none of them implied the others, its linguistic elaboration was modified. In fact, exploratory research showed that, in workflow modelling, the term "process" bears to an operational abstraction (Weske, 2007, p. 5) and "management" comprises the human perspective on the business workflow (Lindsay et al., 2003). Thus, the latter instances were removed. Also, the "order management process" was generalized into "management process" as the former was deemed too case-specific for a literature review. The resulting structure was: "What languages can be used to model a digital management process?".

Appendix C.1.2: Search Scope

Next, the inclusion and exclusion criteria have been spelled out (Purssell & McCrae, 2020, p. 24). Firstly, since Business Process Management grew to be a rigorous and ordinary science only at the beginning of the seventies (Jeston, 2018, p. 136), solely articles published after the 1970 were accepted. In addition, other three criteria are meant to ensure quality of publications. Firstly, articles in press or without peer review were ignored. In fact, this verification process often finds major errors which debase the quality of knowledge. Secondly, for a paper to be accepted, the highest h-index of the authors should be at least one fourth of the years passed since that author's first publication. This precaution ensures that no papers solely written by unqualified scholars are considered. Thirdly, some restrictions fetter the readability and pertinence of results. In fact, only Italian and English publications from the subject fields of computer science, engineering, management, business, and decision science are retrieved. These measures are needed since those are the only languages the author is familiar with and the only perspectives aligning with the theoretical framework adopted for this research question, which can be found in table 8.

Appendix C.1.3: Search Strategy

Regarding the literature catalogues consulted, thanks to its broadness, Scopus was deemed the only strictly necessary one (Ballew, 2009). In fact, it enables to approach the research question from all its disciplinary perspectives within just one database. Moreover, two discipline-specific repositories were used as suggested by Purssell and McCrae (2020, p. 36). Firstly, Business Source Elite (EBSCO) was queried to identify relevant papers in the field of business, management, and decision science. On the other hand, ACM Digital Library was used to stress the viewpoint of engineering and computer science. Thus, the research question is investigated from 5 theoretical standpoints and each of them is served by two databases: Scopus and the respective disciplinary one.

Once this choice is settled, Purssell and McCrae (2020, p. 33) advise proceeding with what they call "Facets Analysis". In practice, this step is carried out by creating the concept matrix refigured in table 14. Here, for each key concept of the research question, synonyms are devised as well as words which relate to the term on a finer and coarser level of abstraction. The identification of these words exploited thesaurus and online open access papers, which however are not quoted as no finding of theirs is used.

Key Concept	Synonym	Narrower	Broader
Model	Representation	Semantic	Design, framework

Business	Enterprise, company, firm, organization	Department, function, actors	Industry, work, corporation
Digital	Computerized	Application, interface	Architecture, system, IT, information
Process	Procedure, method, operation, routine, scheme, workflow	Action, task, step, activity	Value chain, supply chain
Language	Notation, ontology	Formality	Communication

Table 27 Concept matrix for research question one

In accordance with the guidelines, to ensure that none of the synonyms holds for more than one key construct, broader terms such as "methodology" and "technique" were dismissed. Then, these terms were searched in different combinations to extract different results. Furthermore, Lucas (2020) faced a similar research question and exploration of his results revealed new valuable terminology for the investigation. Hence, the strings were augmented with terms such as "review", "study", "analysis" and "comparative", despite they do not directly relate with the search matrix. Next, figure 8 depicts the cyclical search strategy used. Here, rectangles stand for activities, and diamonds with a cross are "inclusive or" splits and or merges (Ligeza, 2011).

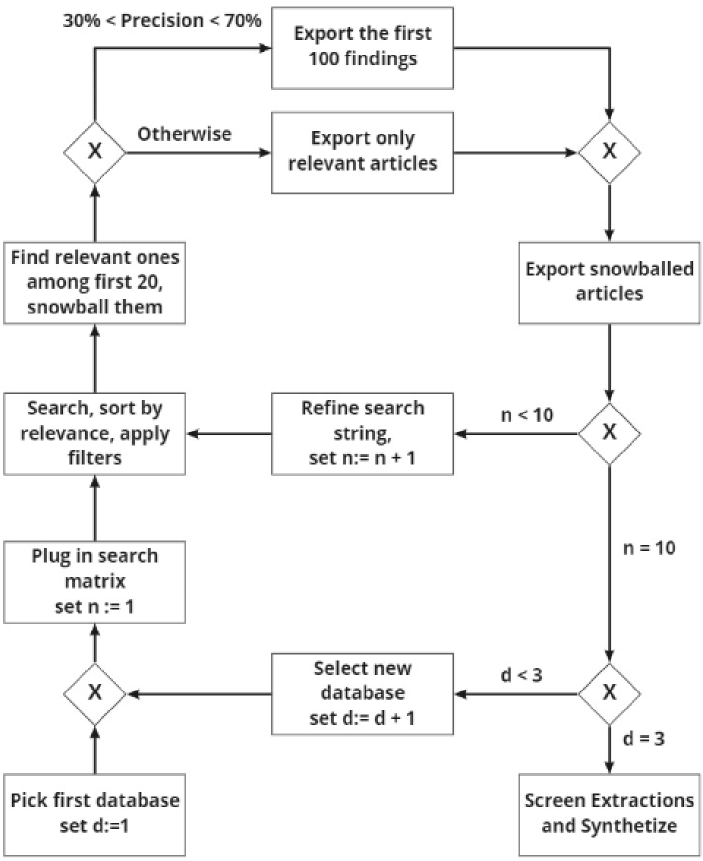

Figure 20 Search strategy

Appendix C.1.3.1: Initializing the search and filtering strategy

In the initial review iteration, the first database is selected and the whole concept matrix is inserted as a string, adding "and" in between rows and "or" among column terms. After triggering the query, results are sorted according to relevance and filtered on various levels. In the first step, articles released before 1970, papers in press, publications not written in English or Italian, documents without peer review, and materials outside the relevant disciplinary fields are screened out by means of search parameters – all the databases enabled this passage to be performed directly on the software. Then, the keyword-selection function is used to overview all the work-words of the retrieved papers and those articles which do not display keywords in alignment with the research question are discarded. The first 20 results of the findings list are then visually reviewed in their title and abstract. As soon as one of them is deemed irrelevant, the search terms which brought to it is identified and noted down for subsequent queries. Next, among the 20 most relevant entries, pertinency is judgementally assessed by the author as the answer to the inquiry: "How much can this paper help answering the research question?" only if the reply is very positive, the instance is considered important.

Appendix C.1.3.2: Extracting Papers

Subsequently, these significant papers are scanned to identify field specific terminology and foster subsequent searches. Moreover, their references titles are overviewed to identify other potentially relevant findings. If the database allows it, this process is performed also on the publications citing the relevant one. Then, snowballing is applied again on each of these snowballed articles iteratively (Badampudi et al., 2015), and all the relevant papers found are extracted in Mendeley reference manager. Therefore, the first way in which a paper can be extracted is either by being a relevant unit of the first 20 fields or by being one of its snowballed articles. This is, however, not the only way in which an article can be retrieved. According to the second method, given the overview of the first 20 papers, the precision of the search is assessed by the following formula:

$$\hat{p}(S) = \frac{R}{20}\% \qquad \text{Eq 7}$$

Where $\hat{p}(S) \in [0\%, 100\%]$ is the estimate of the precision of search string S, and $R \in \mathbb{N}$ is the number of relevant articles among the first 20. Since a search must strike the balance on the trade-off between precision and sensitivity (Montori et al., 2005), it would be suboptimal to strive for maximal accuracy. Hence, if for a given search string S, the precision was between 30 and 70 per cent, the first 100 entries were retrieved. This unconventional extraction is justified inasmuch as papers were sorted by relevance. Thus, on an intuitive level, importance decreases the further an article is from the top and were all the articles extracted, much noise would be brought among the papers to be reviewed, slowing the final analysis greatly. In case $\hat{p}(S) < 30\%$ or $\hat{p}(S) > 70\%$, only the relevant articles among the first 20 instances or their corresponding snowballed papers were exported, if any.

Appendix C.1.3.3: Iterating the search

At this point, if less than 10 searches have been performed on the current database, the search string is refined and inserted again. If more than 100 results were found in a particular search, the string is augmented with "and" operators, otherwise "or" logics are added. In both cases, words are inserted from the search matrix and from the log of terms which produced valuable results previously. In addition, if precision was beneath 50%, terms which yielded insignificant findings are excluded as well as truncations, whereas if it was above 50%, the same strategy was applied as if less than 100 entries had been returned. Then, the search is repeated, the filtering is performed, and results are extracted according to the methodology explained above. After having iterated this process 10 times on the same database, a new repository is adopted, and the first search is performed with the entire concept matrix again.

As of the execution of this procedure, table 15 reports the search strings, databases, and findings for the iterations which had a sufficient precision for extraction on a large scale. In these cases, all the available results ranking higher than the 100th position in relevance were retrieved. However, they alone do not make up for the entire number of important articles because snowballed papers and pertinent ones identified in unprecise searches are not counted in the figures under “Results” in table 15. However, they do are counted in the Prisma flow diagram of figure 9 as it shall be explained later. The reader will also notice that no search from ACM Digital Library has been fully retrieved. In fact, the scope of this journal was heavily computer science-cantered, and little was given about modelling languages. Therefore, no search achieved the needed precision for massive extraction. However, the 4 publications snowballed or picked there concerned unique notations untreated in other databases, and they made the search worth the effort.

Appendix C.1.4: Search Results

Eventually, the search has been performed ten times for each of the three databases, a directory of mined articles has been created and the data extraction phase can begin. This passage takes place in the “Screen Extractions and Synthetize” step of figure 8. After scrutinizing table 15, the reader is presented the screening process and the information extraction phase in this order.

Database	Search Specifications	Results	Precision
Scopus	String: (model* or notation*) and (language*) and (business*) and (process or workflow) and (review or overview or comparative) Subject: Computer Sciecne, Engineering, Decision Science, Business and Management Search In: Title, Abstract, Keyword Key Word: “Business Process”, “Modeling Language”, “Business Process Model”, “Business Process Modeling”, “Business Process Execution Language”, “ULM”, “Business Process Modelling”, “BPMN”, “BPEL”, “Petri Nets”, “Workflow”, “Formal Language”, “Process Model”, “Process Modeling”, “Archimate”, “Industrial Management”, “ArchiMate”, “WS-BPEL”, “Work-Flows”	175	30%
	String: (language* or representation * or notation*) and (model*) and (business) and (process* or activit*) and (review or study or analysis or comparative) Subject: Computer Sciecne, Engineering, Decision Science, Business and Management Search In: Title, Abstract, Keyword Key Word: “Comparative Analysis”, “Comparative Study”, “Business Process”, “System Engineering”, “Information Systems”, “Business Process Model”, “Process Engineering”, “Modeling Languages”, “Business Process Management”, “Business Process Modelling”, “Enterprise Resource Management”, “Business Process Modeling”, “Information Management”, “Administrative Data Processing”, “Language”, “Process Control”, “Requirements Engineering”, “Information Technology”, “Management Information Systems”, “Process Modeling”, “Process Modelling”, “Information Processing”, “Information Science”, “Knowledge Representation”	76	45%
Business Source Elite Business Source Elite	String: (language* or notation*) and (model*) and (business or organization) and (process* or workflow*) and (review or overview or comparative) Search in: Abstract	36	60%

Source: Academic journals Subjects: Literature Reviews, Unified Modelling Language, Comparative Studies, Theory, Petri Nets, Conceptual Models		
String: (business* or organization*) and (process* or workflow*) and (model*) and (language* or notation*) and (review or overview or (comparative and (analyisis or study)) Search in: Abstract Source: Academic Journals Subjects: Information technology, management, business models, industrial management, business enterprises, management science, business process management, business.	40	30%

Table 28 Search log of research question one

Appendix C.1.4.1: Prisma Flow Diagram

To start with, the extracted papers were screened according to the PRISMA guidelines for reporting systematic reviews (Moher et al., 2009). Since all the articles are contained in Medley reference manger, screening the doubles is as easy as pressing a button. In the next step, aptness is assessed from the documents title and abstract, and the suitable ones are tested against h-index criterion. The remaining publications undergo eligibility assessment by means of full text inspection. 17 elements succeed to this point, and they are included in the theoretical analysis. Figure 9 represents this process and reports on the number of papers which undergo each phase. Note that the papers input in the process per database are always greater of equal to the summation of retrieved papers from table 15. This fact occurs because the number in figure 9 also encompass the snowballed articles and the relevant ones coming from unextracted searches.

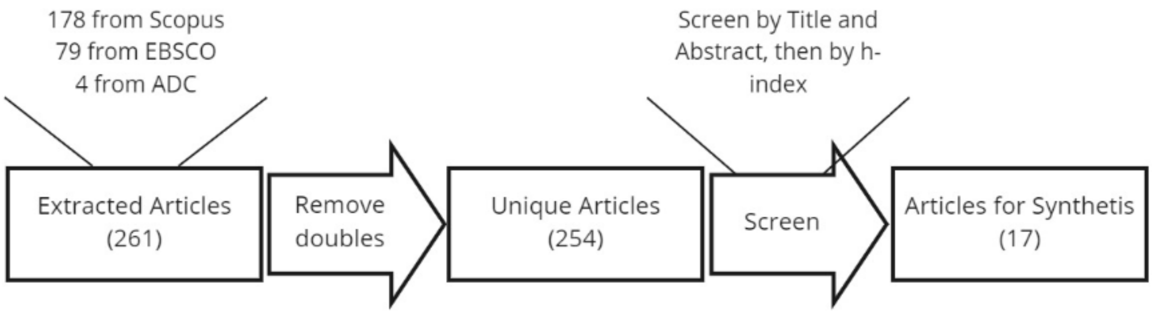

Figure 21 Prisma flow diagram

Appendix C.1.4.2: Literature Matrix

A preliminary step for the synthetization of the results is creating a literature matrix to map concepts against articles and outline their opinion in those regard (Purssell and McCrae, 2020, p. 102). Given the limits of an A4 paper, the structure of table 16 deviates from that of a traditional literature matrix. Moreover, for a glossary of abbreviations, the reader is referenced to table 1.

Topic	**Paper opinion**
Event Driven Process Chain	EPC can be extended into aEPC and C-EPC to increase modelling accuracy (Baier et al., 2010)
	EPC can be augmented into eEPC, which represent operations and information better than Oliveira, KMDL 2.2 and PROMOTE (Ben Hassen et al., 2017)

	eEPC capture operations and information better than RAD, Oliveira, KMDL 2.2, and PROMOTE. They refigure operations better than UML-AD (Ben Hassen et al., 2018).
	EPC have higher expressiveness than IDEF and the same as RAD (Pereira & Silva, 2016).
	They are as clear as YAWL and BPMN 2.0, their expressiveness is superior to that of YAWL and equal to that of UML and BPMN 2.0 (Figl, 2010).
	Their semantic guarantee less pattern coverage than those of general Petri Nets (Recker et al., 2009)
Business Process Management Notation 2.0	Captures functional and informational processes better than eECP, UML-AD, Oliveira, KMDL 2.2 and PROMOTE (Ben Hassen et al., 2017).
	Captures functional and informational routines better than eECP, RAD UML-AD, Oliveira, KMDL 2.2 and PROMOTE (Ben Hassen et al., 2018).
	BPMN 2.0 has higher expressiveness than EPC, RAD, and IDEF, while their score equals that of UML-AD (Pereira & Silva, 2016).
	There are at least 54 BPMN 2.0 extensions tailored to increase its accuracy in data handling in a variety of industries and applications (Zaroru et al., 2019).
	When integrated with ArchiMate, offers significant expressional improvements only on the business layer, being completely indifferent to the other ones (Gill, 2015).
	Their expressiveness is higher than that of YAWL and lower than that of EPC, o the other hand, their clarity is lower that of UML (Figl, 2010).
Unified Modelling Language	Can be instantiated in UML-AD which is lower only to BPMN 2.0 with respect to process representation and it as good as eEPC in capturing the information workflow (Ben Hassen et al., 2017).
	UML-AD is inferior to BPMN 2.0 in respect of operational expressiveness, whereas it is as good as KMDL 2.2 in representing information (Ben Hassen et al., 2018).
	Have the same expressiveness as BPMN 2.0 (Pereira & Silva, 2016).
	When integrated with ArchiMate provides the most performant combination to model high- and low-level process logics (Gill, 2015).
	Is extended by SoaML to describe service-oriented software applications in detail (Gill, 2015).
	It has higher expressiveness and clarity than YAWL, EPC, and BPMN (Figl et al., 2010).
KMDL 2.2	It is the worst language to represent the proactical process flow and it is only better than Oliveira and PROMOTE in information representation (Ben Hassen et al., 2017).
	Ben Hassen et al. (2018) confirms the findings of Ben Hassen et al. (2017) adding that RAD has higher process representation and lower data depiction.
Oliveira	Is only better than KMDL 2.2 in process refiguration and solely better than PROMOTE in information display (Ben Hassen et al., 2017).
	Ben Hassen et al. (2018) confirms the findings of Ben Hassen et al. (2017) adding that Oliveira and RAD are equally capable of capturing information and the latter is better at showing operational routines.
RAD	It is as adept as eEPC to represent practical workflows while it is the worst language to express information dependencies (Ben Hassen et al., 2018).
	Its expressiveness is only superior to that of IDEF (Pereira & Silva, 2016).
PROMOTE	It is better than KMDL 2.2 and PROMOTE in capturing organizational processes and it is superior to none when it comes to express information logics (Ben Hassen et al., 2017).

	It is as poor as RAD in capturing both information and practical workflows (Ben Hassen et al., 2018).
IDEF	It is the language with the lowest expressiveness among the ones analysed (Pereira & Silva, 2016).
S-BPM	Capture data and message exchange among agents better than YAWL (Hence & Malz, 2015).
	FAML is an instantiation of S-BPM for the creation of agent-oriented software logics, it performs worse than ArchiMate in organizational representations and has little visual support (Gill, 2015)
YAWL	Is more suitable to capture physical process temporal dynamics than S-BPM (Hence & Malz, 2015).
	Their clarity and expressiveness are lower or equal to that of UML, BPMN 2.0, and EPC (Figl, 2010).
Petri Nets	Petri nets are universalized in GSPN, that are less expressive than SPA and SAN (Braghetto et al., 2010).
	Basic Petri Nets can be augmented to represent information supporting the workflow (Shih & Leung, 1997).
	Their semantics guarantee more patterns coverage than those of EPC (Recker et al., 2009).
	Basic Petri Nets can be extended to incorporate time, capacity, capability, failure rate, priorities, types of products, defective parts, and storages (Choi et al., 1994).
	Petri Nets have inspired multiple modern modelling languages. Among these, SoftPM and MOPN-SPnet are direct and linear extensions of Petri Nets for software operations modelling (Garcia-Borgonon et al., 2014).
Classification of Business Process Languages	The field of BPM partitions into diagrammatic, mathematical, and linguistic models (ShishKov, 2017).
	Linguistic Models split into rule-based and graph-based models (Lu & Sadiq, 2007).
	Business process modelling languages divide into traditional ones, which aim at communicability such as EPC, object-oriented ones, such as UML, and industrial developed, such as BPMN 2.0 (Mill et al., 2010).
Automata Networks	Can be configured as SAN which have larger expressiveness, scalability, and readability than GSPN and SPA (Braghetto et al., 2010).
Process Algebra	Can be modelled as SPA which have intermediate modelling capabilities between GSPN and SAN (Braghetto et al., 2010).
ArchiMate	It is a high-level Enterprise Architecture and Workflow Modelling language which can be integrated with other notations to enhance its low-level expressiveness up to a point (Gill, 2015).

Table 29 Literature Matrix

Appendix D: Baseline Process Analysis

In the subsequent analysis, motives are given for the values visualized in tables 13 to 15. Before diving into the explanation, it is important to notice that all the classifications and counting processed performed to score the objectives matrices have been confirmed by expert opinion. In practice, they were performed in direct collaboration with the production planners.

Appendix D.1 Measure Performance

In the subsequent passage, the reader finds the automation grades of each activity of the as-is EDCP. This parameter is scored for A1.1 to A3.6, and for each mark, a reason for its assignment is given in the rightmost column of the subsequent table. Then, for each EDCP section, its performance is scored by applying equation 1 using the automation level of its sub-activities as inputs. For example, the performance of the baseline "Update MOs and DOs" is the mean automation level of tasks A1.1 to A1.5, which is $\frac{3+2+2+4+2}{5} = 2{,}6$.

Task	Automation Score	Reason
A1.1	3	The querying software informs about how to be manipulated to perform the extraction
A1.2	2	The excel is to be used to the best of the employee's knowledge, without any real time assistance
A1.3	2	The ERP has specific navigation tools to surf the forecast, which guide the process
A1.4	4	The ERP prescribes the workflow to be followed to carry out the MO and DO creation
A1.5	2	The user is filling the emails with what is possible on the named software only
A2.1	2	The interaction interface of the querying software suggests how the task should be carried out
A2.2	3	The querying software informs about how it should be used optimally
A2.3	2	The user manipulates excel with the sole guidance of what is feasible and unfeasible in it
A2.4	3	Upon printing from the ERP database, the software suggests how to proceed
A2.5	2	The user spells out data manually according to his abilities with Excel
A3.1	2	The reader uses Excel without following any computer assisted workflow, but with his abilities only.
A3.2	2	The deadlines provided in the Excel file give suggestion on how the transportation schedule should behave
A3.3	2	What is feasible on the mailing software informs about how the task should be carried out
A3.4	4	The ERP has specific workflows to follow to carry out this process, and the procedure handles user error by pointing them out.
A3.5	4	Again, the ERP has specific workflows to guide the user and prevent his mistakes or give him opportunities to correct them.
A3.6	2	The online repository and the printing of material is completely up to the user, with the usability of the software as the only guidance

Table 30 Performance Measurement for Baseline Processes

Appendix D.2 Measure Cost

Next, the reader finds the measurement of the cost metric as defined by equation 2. In the following table, the leftmost column indicates what EDCP sub activity is referenced. Then, the second column enumerates types of components in an architecture, whereas column three utters what module of the task architecture corresponds to that description. Eventually, the rightmost column reports how many parts of the task construction can be classified within the row's category. After this counting step, the cost of an EDCP activity is computed as the number of components its architecture is made of. Hence, the cost of "Update MOs and DOs" is $(2 + 1 + 2 + 0 + 1) + (1 + 1 + 1 + 0 + 1) +$

$(1+0+1+0+1)+(3+0+1+0+0)+(1+1+1+0+0)=20$ and the higher this score, the higher the cost of the architecture.

Process Task	Cost Category	Description	Quantity
A1.1	Inputs	One in the query software, one in the excel for manipulation	2
	Outputs	The excel file	1
	Inner Files	The excel output is a logical external file, and the ERP too	2
	Outer Files	none	0
	Inquiries	One to extract data from the ERP DB	1
A1.2	Inputs	The excel for manipulation	1
	Outputs	The excel when manipulation is done	1
	Inner Files	The excel table is an inner logical file	1
	Outer Files	none	0
	Inquiries	The one that allows filtering	1
A1.3	Inputs	The ERP forecast visualizer mask	1
	Outputs	none	0
	Inner Files	The ERP database	1
	Outer Files	none	0
	Inquiries	The one that retrieves forecast slot	1
A1.4	Inputs	Two masks, one for MOs, two for DOs	3
	Outputs	none	0
	Inner Files	The ERP database	1
	Outer Files	none	0
	Inquiries	none	0
A1.5	Inputs	The mailing interface	1
	Outputs	The mailing summary	1
	Inner Files	The mailing database	1
	Outer Files	none	0
	Inquiries	none	0
A2.1	Inputs	The data required for the querying software	1
	Outputs	none	0
	Inner Files	the ERP database	1
	Outer Files	none	0
	Inquiries	One to identity CB MOs	1
A2.2	Inputs	The querying software mask	1
	Outputs	The excel file where data are pasted	1
	Inner Files	The ERP database	1
	Outer Files	none	0
	Inquiries	The one to extract the new MOs	1
A2.3	Inputs	The excel interface	0
	Outputs	none	1
	Inner Files	The excel table is a database in itself	1

	Outer Files	none	0
	Inquiries	One to sort and filter the MOs for CBs	1
A2.4	Inputs	One to extract from the ERP, one to manipulate in excel	2
	Outputs	The excel extraction	1
	Inner Files	The excel table and the ERP database	2
	Outer Files	none	0
	Inquiries	One in the ERP database and one in the excel table to match	2
A2.5	Inputs	The excel interface	1
	Outputs	None	0
	Inner Files	The excel table	1
	Outer Files	none	0
	Inquiries	none	0
A3.1	Inputs	The excel file	1
	Outputs	None	0
	Inner Files	The excel is a database in itself	1
	Outer Files	None	0
	Inquiries	One that gets the painters	1
A3.2	Inputs	The telephone interface	1
	Outputs	None	0
	Inner Files	The excel database	1
	Outer Files	None	0
	Inquiries	none	1
A3.3	Inputs	The mail interface	1
	Outputs	The mail summary	0
	Inner Files	The excel database	1
	Outer Files	None	0
	Inquiries	none	0
A3.4	Inputs	The creation and printing of a withdrawal list calls for the use of 5 interfaces	5
	Outputs	None	0
	Inner Files	The ERP database	1
	Outer Files	none	0
	Inquiries	One that retrieves the painters and one for the material availability	2
A3.5	Inputs	Making a transportation note requires two input interfaces	2
	Outputs	none	0
	Inner Files	ERP database	1
	Outer Files	none	0
	Inquiries	One that gets the painter and one that gets its withdrawal lists	2
A3.6	Inputs	The querying interface of the online database	1
	Outputs	none	0
	Inner Files	The online database, the excel table	2
	Outer Files	none	0

	Inquiries	The one that retrieves the configuration appearance	1

Table 31 Cost Measurement of Baseline Processes

Appendix D.3 Measure Modifiability

In the subsequent table the reader will find the justifications for the measurements of modifiability given in tables 13 to 15. For each EDCP task, its sub-activities are enumerated in the leftmost column. Then, the second one numbers the possible customizations which the ERP may have. For each of them, the third column explains which baseline task architectural component belongs to it and the rightmost column quantifies this value. Then, the numbers are used to score the metric in equation 3. For example, the modifiability of "Update MOs and DOs" is $\frac{2+4}{2} = 3$ as this process entails one ERP added functionality and one altered screen in the system, which respectively have modifiability rank of 2 and 4 by table 11.

Process Task	Modifiability Category	Reason	Quantity
A1.1	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The Querying software collaborates with the ERP to add the functionality COs Extraction	1
	Changed Functionality	none	0
A1.2	New Displays	The Excel display is not in the ERP and thus no variations were performed on ERP screens	0
	Amended Displays	The Excel display is not in the ERP and thus no variations were performed on ERP screens	0
	Automated Logic	No logic is automated, neither in the Excel nor in the ERP	0
	Added Functionality	Despite the Excel software adds the data handling functionality, it does not collaborate with the ERP	0
	Changed Functionality	No ERP functionality was changed	0
A1.3	New Displays	No new displays were added in the ERP	0
	Amended Displays	The forecast display was changed in its front-end so that the planner responsible for performing A1.3 can find forecast slots more easily	1
	Automated Logic	No logic was automated in the ERP	0
	Added Functionality	No functionality was added in the ERP to perform this task	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A1.4	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0

	Automated Logic	No logic was automated in the ERP	0
	Added Functionality	No functionality was added in the ERP to perform this task	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A1.5	New Displays	The task is entirely performed in the mailing software, no changes were performed in the ERP	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No logic was automated in the ERP	0
	Added Functionality	No functionality was added in the ERP to perform this task	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A2.1	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The ERP system collaborates with the querying software to paste all the COs data onto their corresponding MOs	1
	Changed Functionality	No ERP functionality was changed to perform this task	0
A2.2	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The ERP system collaborates with the querying software to perform a peculiar extraction of MOs	1
	Changed Functionality	No ERP functionality was changed to perform this task	0
A2.3	New Displays	The Excel display does not count as ERP display; thus, it is not counted toward the modifiability metric	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	No functionality was added in the ERP to perform this task	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A2.4	New Displays	No unprecedent custom ERP display is used in this operation	0

	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	Although entries are completed thanks to an accessory MOs extraction in the ERP, this action aligns with the software default functionalities.	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A2.5	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	No functionality was added in the ERP to perform this task	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A3.1	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The grouping is performed in Excel; therefore it does not count as an extra ERP functionality	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A3.2	New Displays	The telephone communication does not entail use of ERP	0
	Amended Displays	The telephone communication does not entail use of ERP	0
	Automated Logic	The telephone communication does not entail use of ERP	0
	Added Functionality	The telephone communication does not entail use of ERP	0
	Changed Functionality	The telephone communication does not entail use of ERP	0
A3.3	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The communication by email is an added functionality which does not involve the ERP	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A3.4	New Displays	No unprecedent custom ERP display is used in this operation	0

	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The allocation of material is performed in line with the ERP off-the-shelf functionalities	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A3.5	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The legal documentation handling only uses the ERP traditional functionalities	0
	Changed Functionality	No ERP functionality was changed to perform this task	0
A3.6	New Displays	No unprecedent custom ERP display is used in this operation	0
	Amended Displays	No display was customized to perform this operation	0
	Automated Logic	No ERP logic was automated in the execution of this operation	0
	Added Functionality	The web operation of bike design creation does not concern ERP utilization	0
	Changed Functionality	No ERP functionality was changed to perform this task	0

Table 32 Modifiability Measurement for Baseline Process

Appendix D.4 Measure Resilience

In the following section the reader is presented the data gathered to compute the resilience metrices. This value is analysed under three perspectives: input vetting, redundancy for backup and caching. For each of the architectural components where these ideas could have been implemented, whether they are in place is assessed. Then, this information is fed into equation 4 and the resilience index is tracked. For example, “Update MOs and DOs” has a resilience of 66% because it implements data redundancy in all the 4 feasible places. Moreover, the same occurs with caching, whereas input vetting seems to be directly implemented nowhere. Hence, $\frac{100\%+100\%+0\%}{3} \approx 66\%$

Category	Description	Implemented
A1.1-A1.5		
Redundancy for Backup		
COs Extraction	COs can be extracted directly from the ERP with more effort	1
Data Handling	Data can be handled on another open-source software	1
Forecast Visualizer	The forecast can be viewed in the material planning section	1

DO MO, insertion	DOs and MOs can be created automatically, then modified	1
Mail Table	There exists other appropriate mailing software	1
Caching		
Forecast Slots	Exist both locally and on the ERP system	1
MOs and DOs	Exist both locally and on the ERP system	1
Input Vetting		
Queuing Software	No check for malicious inputs, only prevention	0
Excel Computation	No check for malicious inputs, only prevention	0
ERP forecast mask	No check for malicious inputs, only prevention	0
ERP MO, DO Mask	No check for malicious inputs, only prevention	0
Mail Software	No check for malicious inputs, only prevention	0
A2.1-A2.5		
Redundancy for Backup		
Update MO query	Can be carried out manually in the ERP	1
MO extraction query	Can be performed by a series of ERP extractions	1
Excel Data Manipulation	Can be carried out in another table-based software	1
ERP MOs extraction	Could be implemented in the querying software	1
Caching		
Excel CBs shape and logistics	Can be retrieved from the ERP with great effort	1
Input Vetting		
MO Update query	No check for malicious inputs, only prevention	0
MO extraction query	No check for malicious inputs, only prevention	0
MO Excel Manipulation	No check for malicious inputs, only prevention	0
ERP MO Extraction	No check for malicious inputs, only prevention	0
A3.1-A3.6		
Redundancy for Backup		
CB Excel data handling	Other software can be used for this purpose	1
Painter Communication	Other software can be used for this purpose	1
Mailing actors	Other software can be used for this purpose	1
Allocate withdrawal	Other ERP means enable this but only partially	0
Legal Recording	The only alternative would be paperwork	0
Shape Creation	Some might be reproduced from local files but not all	0
Caching		
Online Repository	The data in there is not cached	0
ERP legal movements	This information is recorded in local repositories too	1
Input Vetting		
Excel CB input	Excel does not have vetting instruments	0
Mailing	The email itself does not have vetting tools	0
ERP material planning	This ERP section does not have vetting tools	0
Online repository	This ERP does not have vetting tools	0

Table 33 Resilience Measurement for Baseline Processes

Appendix D.5 Measure Duration

In the subsequent section, the reader is presented how data for self-reported durations was collected and manipulated for practical purposes. To start with, the EDCP activities were segmented to facilitate the responsible planner in reporting their completion time. This division was performed based on the number of units flowing through the process in a specific workflow fragment. For instance, if a batch is the set of CBs to be processed on Monday morning, activities A1.1 and A2.2 were united because they both are performed once for each batch, whereas tasks A1.3 to A1.5 were aggregated because they are performed once for each CB demanded. This enables the planner to express duration as a function of the unit type, he processes during the activity. It is the author's duty to morph this measurement into some standardized metric afterwards. In this regard, table 34 reports process fragments, their reported duration and the set of CBs being processed in a single execution.

EDCP Section	Fragment	Self-Reported Duration	
		Duration	Measurement
Update MO and DO	A1.1-A1.2	60-80	Seconds per batch
	A1.3-A1.5	160-180	Seconds per order line
Update CB Excel	A2.1-A2.4	100-120	Seconds per batch
	A2.5	80-100	Seconds per order line
Plan Transport	A3.1-A3.2	260-640	Seconds per batch
	A3.3-A3.5	260-340	Seconds per withdrawal list
	A3.6	80-100	Seconds per order line

Table 34 Data collected from Planner Interview

To determine bottlenecks accurately within an EDCP section, it is important to standardize the measurement into a unique unit. In this case, it is reasonable to choose to reduce them all to seconds per order line. However, this requires knowing how many CBs are in a batch and in a withdrawal list. This information was gained by means of expert interview, and planners reported that the mean batch size is 38 custom bikes, and there are about 7 elements in a withdrawal list. Hence, the durations reported for batches and withdrawal lists can be translated into durations per bikes through division by these values, and the results are reported in tables 13, 14 and 15 of the section 4.2.4. For example, the execution of tasks A3.3 to A3.5 takes between 200 and 340 seconds per withdrawal list. But since there are about 7 entries in each of them, it can be inferred that its correspondent duration is within $\left[\frac{260}{7};\frac{340}{7}\right]$ or $[37{,}14; 48{,}57]$ that is $[38; 49]$ if rounded to the closest second.

Appendix E: Target Process Analysis

Appendix E.1 Measure Performance

The subsequent table displays the automation levels of each target EDCP task component. Scores are retrieved from table 9 according to the reason explained in the rightmost column. These values are then used to compute the overall performance of the processes "Update MOs and DOs", "Update Excel" and "Transport Tasks" by means of equation 1. For example, the performance of the to-be "Update MOs and DOs" is $\frac{7+7+7+5}{4} = 6{,}5$.

Task	Automation Score	Reason
T1.1	7	The reading of the CO rows is completely automatic and the counters initiation and the stopping condition evaluation
T1.2	7	Getting the forecast slot is completely automatic in the ERP
T1.3	7	The creation of the MOs and the DOs is completely automatic
T1.4	7	The forecast is updated completely autonomously in its quantity
T1.5	5	The system returns what detailed changes which have been done to the forecast, which are needed for accounting analysis, implicitly suggesting what analysis to perform with them

T2.1	7	The ERP compiles the Mashup page automatically upon loading, and the script triggers the visualization as soon as the page is opened
T2.2	7	The retrieved CBs configurations are decoded automatically by the ERP script; hence, it is fully automated
T2.3	5	Possible locations are displayed automatically. However, the reader is still to choose among the sifted set of feasible places for a bike to be. Thus, is only prescriptive.
T3.1	7	The retrieval of the MVRP information is fully automated
T3.2	7	Feeding and running the MVRP are completely automated tasks
T3.3	7	The ERP mashup and the BtoB application are autonomously updated after the problem execution
T3.4	5	The ERP displays which Mashups can be opened and within it, the structure suggests the best actions to pursue although actors are informed automatically
T3.5	7	Materials are allocated automatically by running the ERP APIs with the information resulting from the MVRP
T3.6	5	Documents need human approval for printing, but once this is gained, they are automatically performed

Table 35 Target Processes Performance Measurement

Appendix E.2 Measure Cost

As follows the cost matric is scored for each of the target processes sub-component. These values are then convoluted into the cost indicator of equation 2 and it indicates how pricy a reengineered process will be in a similar fashion of that seen in appendix D.2

Process Task	Cost Category	Description	Quantity
T1.1	Inputs	The human input required is the closure of the CO insertion panel	1
	Outputs	No human output is given to this task	0
	Inner Files	No internal database is accessed	0
	Outer Files	No external database is accessed	0
	Inquiries	The CO is investigated to retrieve its lines, yet it is on a front-end level rather than on the back end	1
T1.2	Inputs	No human input needed	0
	Outputs	No human output given	0
	Inner Files	The forecast section of the database is accessed	1
	Outer Files	No external file used	0
	Inquiries	The forecast section is queried to retrieve feasible slots	1
T1.3	Inputs	No human input needed	0
	Outputs	No human output given	0
	Inner Files	The ERP database is accessed to add the MOs and the DOs	1
	Outer Files	No external database is accessed	0
	Inquiries	No inquiry performed	0
T1.4	Inputs	No human input needed	0
	Outputs	No human output given	0
	Inner Files	The ERP database is updated by changing the forecast for the present date	1
	Outer Files	No external database is accessed	0
	Inquiries	The forecast to be changed are retrieved according to the identification formerly gained, and they are changed	1

T1.5	Inputs	No human input needed	0
	Outputs	The changes occurred in the database are reported to the sales accountant by means of an output screen	1
	Inner Files	No inner file accessed as the returned data is in the local memory	0
	Outer Files	No external database is accessed	0
	Inquiries	No inquiry performed	0
T2.1	Inputs	The Mashup screen must be activated to set up	1
	Outputs	The same Mashup returns the MOs data as output	1
	Inner Files	The information is retrieved from the ERP inner database	1
	Outer Files	No outer file used in this process	0
	Inquiries	The ERP database is surfed by means of a query	1
T2.2	Inputs	No further action is needed from the operator for the configurations to expand	0
	Outputs	The Mashup columns will be filled by the decoded bike configuration	1
	Inner Files	The decoding logic is locally implemented in the script, no query is performed	0
	Outer Files	No outer file used in this process	0
	Inquiries	No inquiry performed in this process	0
T2.3	Inputs	The ERP script autonomously proceeds, no human intervention required	0
	Outputs	The Mashup outputs the locations where a specific bike may be	1
	Inner Files	The locations are retrieved from the inner ERP database	1
	Outer Files	No outer file used in this process	0
	Inquiries	The locations are retrieved by querying the ERP database	1
T3.1	Inputs	The mashup must be opened, and start must be pressed	1
	Outputs	No output screens or displays	0
	Inner Files	The DB software is used as well as the ERP one	2
	Outer Files	No outer databases to be used	0
	Inquiries	Both the used databases are queried	2
T3.2	Inputs	No human inputs taken	0
	Outputs	No output screens or displays	0
	Inner Files	No inner files used	0
	Outer Files	No outer databases to be used	0
	Inquiries	No query run	0
T3.3	Inputs	No human inputs taken	0
	Outputs	The data generated by the MVRP is output in a Mashup table	2
	Inner Files	The web application itself is a database of information and its used	1
	Outer Files	No outer databases to be used	0
	Inquiries	No query run	0
T3.4	Inputs	The variations are collected in a mashup screen	1
	Outputs	The new schedule is outputted both to painters online and to planners on the local mashup	2
	Inner Files	The ERP inner file is used along with the DB software	2
	Outer Files	No outer databases to be used	0
	Inquiries	The ERP is inquired as well as the ERP software	2
T3.5	Inputs	No human inputs taken	0
	Outputs	No output screens or displays	0

	Inner Files	The Mashup table is used, and it is a file itself, whereas the ERP file is employed too	2
	Outer Files	No outer databases to be used	0
	Inquiries	A query is made on the ERP database and one on the Mashup table	2
T3.6	Inputs	No human inputs taken	0
	Outputs	The printed documents are outputs	1
	Inner Files	The online application is used to retrieve the configurations	1
	Outer Files	No outer databases to be used	0
	Inquiries	The online database is inquired to find the configurations	1

Table 36 Target Process Cost Measurement

Appendix E.3: Measure Modifiability

As follows the modifiability matric is scored for each of the target processes sub-component. These values are then convoluted into the cost indicator of equation 3 and it indicates how modifiable a reengineered process will be in a similar fashion of that seen in appendix D.3.

Process Task	Modifiability Category	Reason	Quantity
T1.1	New Displays	No displays added	0
	Amended Displays	No displays integrated	0
	Automated Logic	The new logical steps are added in the process	1
	Added Functionality	The added logics are implemented by added functionalities	1
	Changed Functionality	No functionality changed	0
T1.2	New Displays	No displays added	0
	Amended Displays	No displays integrated	0
	Automated Logic	The forecast slot identification is automated	1
	Added Functionality	The functionality to search through the forecast must be added	1
	Changed Functionality	No functionality changed	0
T1.3	New Displays	No displays added	0
	Amended Displays	No displays integrated	0
	Automated Logic	The creation of MOs and DOs is automated	1
	Added Functionality	The create MO and create DO functionalities are already in the software	0
	Changed Functionality	No functionality changed	0
T1.4	New Displays	No displays added	0
	Amended Displays	No displays integrated	0
	Automated Logic	The forecast changes are updated by means of automated logics	1
	Added Functionality	No functionality added	0
	Changed Functionality	No functionality changed	0
T1.5	New Displays	Additional information on forecast variations is output in a new window	1
	Amended Displays	No displays integrated	0
	Automated Logic	The communication of variations is automated	1
	Added Functionality	The window creation and filling is a newly implemented function	1
	Changed Functionality	No functionality changed	0
T2.1	New Displays	The visualization display is a new mashup	1
	Amended Displays	No amended Display	0

	Automated Logic	The logic by which the visualization display is filled is new and automated	1
	Added Functionality	The extraction of CBs alone is a new functionality	1
	Changed Functionality	No changed functionality	0
T2.2	New Displays	No new displays	0
	Amended Displays	No amended Display	0
	Automated Logic	The expansion of the configuration is automated	1
	Added Functionality	The configuration expansion is an added functionality	1
	Changed Functionality	No changed functionality	0
T2.3	New Displays	No new display	0
	Amended Displays	No amended Display	0
	Automated Logic	The extraction of locations is automated per row	1
	Added Functionality	The extraction of locations already exists	0
	Changed Functionality	No changed functionality	0
T3.1	New Displays	No new displays	0
	Amended Displays	No amended displays	0
	Automated Logic	The data retrieval procedures are automated	1
	Added Functionality	The integration of DB software is an added functionality	1
	Changed Functionality	The painter assignment is a changed functionality	1
T3.2	New Displays	No new displays	0
	Amended Displays	No amended displays	0
	Automated Logic	The solution procedure of the MVRP is an automated logic	1
	Added Functionality	The ability to solve the system is an added functionality	1
	Changed Functionality	No Functionalities are changed	0
T3.3	New Displays	One on the net for painters, one in the ERP for planners	2
	Amended Displays	No amended displays	0
	Automated Logic	The logics updating both displays have been automated	2
	Added Functionality	The logics to update both displays are new functionalities	2
	Changed Functionality	No Functionalities are changed	0
T3.4	New Displays	No new displays	0
	Amended Displays	The initial mashup is amended to accommodate variations	1
	Automated Logic	The dynamic by which the MVRP is adjusted is automated	1
	Added Functionality	The ability to rerun the MVRP is an added functionality	1
	Changed Functionality	No Functionalities are changed	0
T3.5	New Displays	No new displays	0
	Amended Displays	No amended displays	0
	Automated Logic	The allocation of materials is automatic	1

	Added Functionality	Materials allocation is an existing functionality	0
	Changed Functionality	No Functionalities are changed	0
T3.6	New Displays	No new displays	0
	Amended Displays	No amended displays	0
	Automated Logic	The logic by which a configuration is offered for printing is an automated logic	1
	Added Functionality	This new automated functionality is also an added one	1
	Changed Functionality	No Functionalities are changed	0

Table 37 Target Process Modifiability Measurement

Appendix E.4: Measure Resilience

As follows the resilience matric is scored for each of the target processes sub-component. These values are then convoluted into the cost indicator of equation 4 and it indicates how resilient a reengineered process will be in a similar fashion of that seen in appendix D.4.

Category	Description	Implemented
T1.1-T1.5		
Redundancy for Backup		
Read Current Row	The current row cannot be read otherwise in real time	0
Get Forecast Slot	The forecast slot can be gained from another ERP mask	1
Create MO and DO	The APIs seem to be the only viable automatable instrument to perform this task	0
Update Forecast	The forecast can be updated completely by hand at the end of the process	1
Return Information	Information can be inspected in the forecast visualizer ERP mask, without having it displayed	1
Caching		
Forecast Slots	The forecast slots exist on a separate software that offers backup	1
MOs and DOs	The overview of MOs and DOs for all the new and old CBs can be found in the ERP only	0
Input Vetting		
CO Insertion	When a CO is inserted, no check is done for malicious intentions	0
T2.1-T2.3		
Redundancy for Backup		
Query, visualize MOs	MOs can be visualized by the Mashup logic only, but some would not be CB then	1
Expand Configurations	Configurations can be expanded by the Mashup itself	1
Get Locations	Locations could be inserted by means of a receive channel from a GPS application	1
Caching		
CB shape	The shapes can be visualized on the COs inserted as well	1
CB location	The locations can be inserted manually, and the workflow would still work	1
Input Vetting		
ERP Table	The Mashup table is protected only by the ERP access barriers, it does not have input vetting instruments itself	0

T3.1-T3.6		
Redundancy for Backup		
Set Up Data	Some fragments of the data could be collected otherwise, but not all of them	0
Run MVRP	There is no backup solutions for the failing of the MVRP as a hand solution would be unfeasible given the complexity	0
Inform Actors	Actors can be informed by mail and excel tables as it was so far	1
Update Variations		0
Allocate	The allocation can be performed by hand and the workflow would be unchanged	1
Print Documents	Documents can be printed manually without compromising the process	1
Caching		
DB Software	The database software does not have a second repository for all its data, but only for a fraction	0
ERP Repository	The ERP repository data is all backed by other databases, at least in regard of CBs	1
Input Vetting		
Vary Set Up Data	The varying setup data does not have vetting	0
Print Documents	The printing documents does as a malicious print would be noticed by the staff immediately	1

Table 38 Target Process Resilience Measurement

Appendix F: Analytical Hierarchy Process

As follows the most relevant matrices of the analytical hierarchy process are displayed. Firstly, figure 22 shows the pairwise comparison needed to establish the score of performance, cost, modifiability, and resilience. Then, figure 23 portrays these scores standardized so that each matrix cell in figure 23 reports its correspondent value of figure 22 divided by its column summation in that same matrix. As of figure 24, the pairwise comparison was given by the decision maker and importance was determined as row average. Then, its percentage was gained by reporting importance scores into fractions of one. These values are not strictly needed for computations. However, they are the importance displayed in table 8 and thus, their determination is explained here for clarity purposes. Finally, each column in the matrix of figure 25 corresponds to the row average of the respective matrix in figure 23, and the final scores are determined as a matrix multiplication between this table and the importance vector. To conclude, the consistency test was performed as explained by Winston & Goldberg, (2004, p. 781). In this fashion, this execution has a maximum lambda of 4,15 ($\lambda_{max} \approx 4{,}15$). Therefore, it has a consistency index of 5,05% ($CI \approx 5{,}05\%$) and a consistency ratio of 5,61% ($CR = 5{,}61\%$). Hence, it is accepted, and the decision maker is deemed consistent.

Performance	T1	T2	T3
T1	1,00	6,00	0,25
T2	0,17	1,00	0,13
T3	4,00	8,00	1,00

Cost	T1	T2	T3
T1	1,00	4,00	8,00
T2	0,25	1,00	4,00
T3	0,13	0,25	1,00

Modifiability	T1	T2	T3
T1	1,00	2,00	3,00
T2	0,50	1,00	3,00
T3	0,33	0,33	1,00

Resilience	T1	T2	T3
T1	1,00	4,00	5,00
T2	0,25	1,00	2,00
T3	0,20	0,50	1,00

Figure 22 AHP Alternatives' Unstandardized Inputs for Performance, Cost, Modifiability and Resilience

Performance	T1	T2	T3
T1	0,19	0,40	0,18
T2	0,03	0,07	0,09
T3	0,77	0,53	0,73

Cost	T1	T2	T3
T1	0,73	0,76	0,62
T2	0,18	0,19	0,31
T3	0,09	0,05	0,08

Modifiability	T1	T2	T3
T1	0,55	0,60	0,43
T2	0,27	0,30	0,43
T3	0,18	0,10	0,14

Resilience	T1	T2	T3
T1	0,69	0,73	0,63
T2	0,17	0,18	0,25
T3	0,14	0,09	0,13

Figure 23 AHP Alternatives' Standardized Inputs for Performance, Cost, Modifiability and Resilience

	Perfromance	Cost	Modifiability	Resilience	Importance	In Percentage
Perfromance	1,00	1,00	6,00	6,00	3,50	53,50%
Cost	1,00	1,00	2,00	3,00	1,75	26,75%
Modifiability	0,17	0,50	1,00	1,00	0,67	10,19%
Resilience	0,17	0,33	1,00	1,00	0,63	9,55%

Figure 24 Attributes Importance Assessment

	Perfromance	Cost	Modifiability	Resilience	Final Score
T1	0,26	0,70	0,52	0,68	2,91
T2	0,06	0,23	0,33	0,20	0,97
T3	0,68	0,07	0,14	0,12	2,67

Figure 25 AHP Final Score Computation