D5.10 – i4Q Manufacturing Line Reconfiguration Guideline v2

WP5 – BUILD: Rapid Manufacturing Line Qualification and Reconfiguration v2

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EXTERNAL ANNEXES/ SUPPORTING DOCUMENTS	None		
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ABSTRACT	This document is a Technical Specification document about the development of the i4Q Manufacturing Line Reconfiguration Guideline (i4Q^{LRG}). This document it is an update of deliverable 5.4 Manufacturing Line Reconfiguration Guideline. This document which provides a thorough description and analysis of the functionalities, features, and the current implementation status. It provides an in-depth technical overview of the principal functional sub-components (i.e., features) of the Solution.		

Document History

VERSION	ISSUE DATE	STAGE	DESCRIPTION	CONTRIBUTOR
0.1	07-Nov-2022	ToC	Table of Contents Creation	UPV
0.2	25-Nov-2022	Draft	First Version of the Technical deliverable available for internal review	UPV
0.3	02-Dec-2022	Internal Review	Internal Review	FBA, FARPLAS
0.4	05-Dec-2022	Draft	Addressing comments from internal reviewers	UPV
1.0	30-Dec-2022	Final Document	Final quality check and issue of final document	CERTH

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ABBREVIATIONS/ACRONYMS

ALBP	Assembly Line Balancing Problem
BCMP	Balancing with Choice of Machine Problem
BESP	Balancing with Equipment Selection Problem
BRTMP	Balancing with Rotary Table Machine Problem
CNC	Computer Numerical Control
CRMS-MS	Celular Reconfigurable Manufacturing Systems – Machine Selection
I4Q	Industrial data services for Quality Control in Smarta Manufacturing
IRTS	Inbound Reconfigurable Transportation Systems
LRG	Manufacturing Line Reconfiguration Guideline
LRT	Manufacturing Line Reconfiguration Toolkit
PDF	Portable Document Format
RML	Reconfigurable Manufacturing Line
RMS	Reconfigurable Manufacturing Systems
RMS-MS	Reconfigurable Manufacturing Systems – Machine Selection
RMS-SP	Reconfigurable Manufacturing Systems – Scalability Planning
SFLP	Static Facility Layout Problem
TLRP	Transfer Line Reconfiguration Problem

Executive summary

This document presents an executive explanation of the **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}) Solution providing the general description, the technical specifications and the implementation status. It is an updated deliverable with respect to its previous version D5.4 Manufacturing Line Reconfiguration Guideline. The deliverable **D5.10** is the Source Code of the i4Q^{LRT} Solution that is in a private repository of Gitlab: https://gitlab.com/i4q.

The documentation associated to the i4Q^{LRG} Solution is deployed on the website http://i4q.upv.es. This website contains the information of all the i4Q Solutions developed in the project "Industrial Data Services for Quality Control in Smart Manufacturing" (i4Q). The direct link to the i4Q^{LRG} Solution documentation is http://i4q.upv.es/20_i4Q_LRG/index.html.
Such documentation is structured according to:

- General description
- Features
- Images
- Authors
- Licensing
- Pricing
- Installation requirements
- Installation Instructions
- Technical specifications of the solution
- User manual

Document structure

Section 1: Contains a general description of the **i4Q Manufacturing Line Reconfiguration Guideline**, (i4Q^{LRG}) providing an overview and the list of features. It is addressed to final users of the i4Q Solution.

Section 2: Details the implementation status of the **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}), explaining the status, new implementation and version history.

Section 3: Provides the conclusions.

APPENDIX I: Provides the PDF version of the **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}) web documentation, which can be accessed online at:

http://i4q.upv.es/20_i4Q_LRG/index.html

1. General Description

1.1 Overview

The **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}) solution consists of a guideline from **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}). The **guideline** does not require digital technologies for development. Furthermore, **data analytics** and **visualisation** will use a web-based interactive development environment for code and data. This software is flexible to configure the user interface and provide support in data science, scientific computing, and machine learning. This web uses the contents of the guide in natural language dialogs to support the end users. To provide this web, it uses the sphinx library. This library is an open-source package that provides a fast and flexible data structure that facilitates working with relational and structured data. Sphinx was originally created for Python documentation, but it provides excellent facilities for documenting software projects in a variety of languages.

1.2 Features

1. The i4Q Manufacturing Line Reconfiguration Guideline (i4Q^{LRG}) is a solution that consists of a guideline from i4Q Manufacturing Line Reconfiguration Toolkit (i4Q^{LRT}).
2. This solution uses the guideline's contents in natural language dialogs to support users.
3. This guideline provides information about the different algorithms.

2. Implementation Status

2.1 Current implementation

The **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}) solution adopts a service approach where each algorithm is defined.

- Prepare the environment to be deployed in any system through Docker or Kubernetes.
- Generate the files so that by means of Continuous Integration the service image is automatically generated.
- Prepare the environment so that the web documentation is done automatically, just by adding the algorithm in the specific directory.

The solution has now been developed to be deployed as a web service. This website will provide information on possible reconfiguration problems with a first section about Reconfigurable Manufacturing Systems (RMS) and Reconfigurable Manufacturing Line (RML) definitions.

It will define the problem and the objective to be achieved, as well as the data inputs and outputs and the Algorithm to be used and other sections that may be interesting for the problem to be addressed. Some of these issues will be about:

- **Assembly Line Balancing Problem (ALBP):** ALBP consists of distributing the total workload for manufacturing any unit of the product to be assembled among the workstations along the line (Ascheri, A. (2016). Any type of ALBP consists in finding a feasible line balance, i.e., an assignment of each task to a station such that the precedence constraints and further restrictions are fulfilled (Scholl et al., 2008).
- **Transfer Line Reconfiguration Problem (TLRP)**: TLRP consists of adapting the configuration of the manufacturing line to meet production demands. The aim of reconfiguration is to minimize the investment cost required to upgrade an existing transfer line. Such decisions must be made considering technological and compatibility constraints between operations and equipment (Makssoud et al., 2014).
- **Balancing with Equipment Selection Problem (BESP)**: Each device is defined by the set of operations it can perform and their cost. In the general case, several devices are capable of performing the same operation, but only one will be selected at the configuration stage. The optimisation problem consists of determining the number of stations and selecting a subset of boxes from a given set to assign to stations.
- **Balancing with Choice of Machine Problem (BCMP):** The optimisation problem consists of dividing the operations into workstations and determining the type and number of parallel machines installed at each station as well as the positioning of the workpiece at each station while respecting the given constraints and reducing the total cost of the line. This problem has been formulated for parallel machining lines.

- **Balancing with special machine design: Moving Table Machine Problem (BMTMP):** When designing a sliding table machine, the optimisation goal may be to reduce machine cost or cycle time, as the configuration with a single active workstation makes machining the part slower.
- **Balancing with special machine design: Rotary Table Machine Problem (BRTMP):** The problem of optimising the configuration of rotary table machines is to reduce the total cost of the machine by determining the number of workstations and multispindles to be installed at each workstation to perform all machining operations and respecting the given technological requirements and technical constraints.
- **Inbound reconfigurable transportation systems (IRTSs):** This problem focuses on inbound transport systems as they are one of the main areas of application of reconfigurability concepts. multiple independent modules will have to be designed for the implementation of alternative configurations of inbound logistics systems.
- **Static Facility Layout Problem (SFLP):** This type of problem is often approached from a continuous formulation, as it tries to minimise the quantity/cost of the material flow from the delivery point of the facility to the collection point of the facility.
- **Dynamic facility layout problem (DFLP):** The location of facilities in the plant area, often referred to as the "facility layout problem", is known to have a significant impact on manufacturing costs, work in process, lead times and productivity (Solimanpur and Kamran, 2010). The objective of this problem is to determine a layout for each period in the planning horizon, minimizing the sum of material handling costs, for all periods, and the sum of reorganization costs between time periods (Drira et al., 2006).
- **Multi-Facility Layout Problem (MFLP):** This problem involves the physical organization of departments inside several facilities, considering two different concerns: the location of departments within a group of facilities, and the location of departments inside each facility itself (Azevedo et al., 2017).
- **Reconfigurable Manufacturing Systems for Scalability Planning (RMS-SP):** The objective of scalability planning is to minimize the number of machines needed to meet a new market demand (Wang and Koren, 2013).
- **Reconfigurable Manufacturing Systems for Machine Selection (RMS-MS):** The selection of the machines is based on two main criteria respectively minimum total cost and minimum total time (Bensmaine et al., 2013).
- **Celular Reconfigurable Manufacturing Systems for Machine Selection (CRMS-MS):** This problem involves the design and loading of Cellular Reconfigurable Manufacturing Systems in the presence of alternative routing and multiple time periods. These systems consist of multiple reconfigurable machining cells, each of which has Reconfigurable Machine Tools and Computer Numerical Control (CNC) machines (Eguia et al., 2017).

2.2 New improvements

A section has been introduced within the explanation of the different problems of the algorithm. This algorithm will also be introduced in the catalog that offers the Manufacturing Line Reconfiguration Toolkit (LRT) solution. Moreover, a section has been added to provide instructions on how to use the LRT solution. We have improved the backend of the solution allowing to optimize the implementation of new algorithms. On the other hand, we have shared this solution with i4Q Pilots and developed one of them for a specific use case. This will be deployed together with the LRT solution.

2.3 History

Version	Release date	New features
V0.1	15/04/2022	Web Structure and first algorithm
V1.0	16/05/2022	First Implementation
V1.1	15/11/2022	Manual LRT
V1.2	30/11/2022	Add algorithm section

Table 1. History of i4Q^{LRT} versions

3. Conclusions

Deliverable D5.10 Manufacturing Reconfiguration Guideline is a specification document that provides an in-depth overview of the i4Q^{LRG} solution. It describes in detail the role, functionalities, and conceptual architecture of i4Q^{LRG}. It presents a study detailing the main features of the solution to clarify the key functionalities and objectives of the i4Q^{LRG} solution. On the other hand, this solution presents a set of problems and solutions to different reconfiguration challenges. It presents us with an objective, the data to be considered, and the final algorithm. The current state of implementation of i4Q^{LRG} is detailed in detail, presenting the significant progress of this global development.

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Appendix I

The PDF version of the **i4Q Manufacturing Line Reconfiguration Guideline** (i4Q^{LRG}) web documentation can be accessed online at: http://i4q.upv.es/20_i4Q_LRG/index.html