MPDesign

Tutorial document

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TU/e

SHOP4CF

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Introduction

MPDesign is a tool that supports the design of manufacturing processes as part of a Manufacturing Process Management System. The tool helps collect information on task requirements in terms of abilities and authorizations needed to perform these tasks, as well as the expected inputs and produced outputs of tasks. This information is cross-checked with information on the available human and robotic agents, which are potential actors for the tasks. The outcomes of the analysis can be exported and easily used in executable MPMS process models. They also provide immediate insights into the availability of the right resources and quality aspects of manufacturing processes. This allows factory managers to assign workers to tasks fitting their qualifications, allocate robotic agents to tasks which may be harmful to humans, and adequately plan upskilling of the personnel. At the same time, the tool verifies the integrity of the modelled process by analyzing the completeness of inputs and outputs and their proper flow.

This document serves as a guide on how to use the MPDesign. The entire procedure of gathered data analysis is presented in a step-by-step manner. Also, the installation details are presented for user convenience.

License

Acknowledgements

MPDesign tool and all documents related to its usage are the research work that has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 873087 (SHOP4CF).

Installation

The MPDesign is ready to use and freely available for download in the GitHub[1] repository as an executable Microsoft Access application. In case the user does not possess a viable Access license, the freely available Microsoft access runtime environment[2] may be used.

MPDesign can be installed on a PC with Windows operating system and standard hardware parameters.

Note: At the moment the MPDesign requires setting the language for non-Unicode programs to Polish. This issue will be fixed in the next release of the tool. In order to change the language setting, open the "Region" setting (e.g. by typing "region" in the task bar search box). Change the tab to "Administrative" and select "Change system locale…"

[1] https://github.com/ZDomagala-Schmidt/MPDesign
[2] https://support.microsoft.com/en-us/office/download-and-install-microsoft-365-access-runtime-185c5a32-8ba9-491e-ac76-91cbe3ea09c9

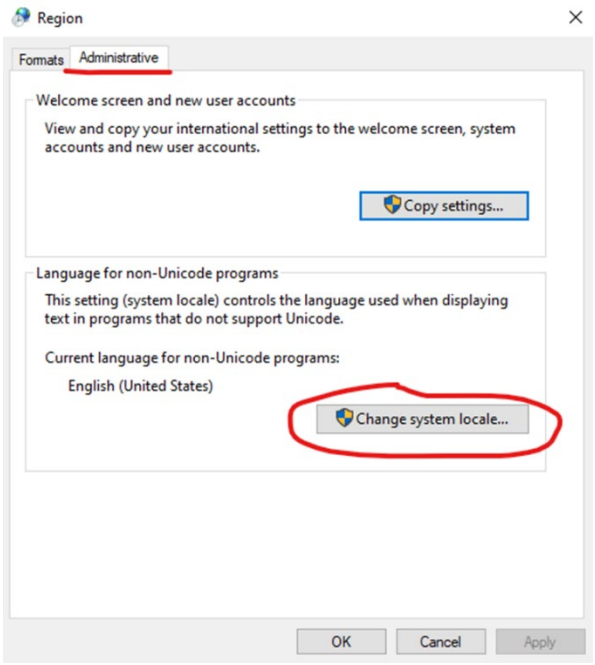

Figure 1. Changing the language for non-Unicode programs - first step

Next change the system locale to Polish.

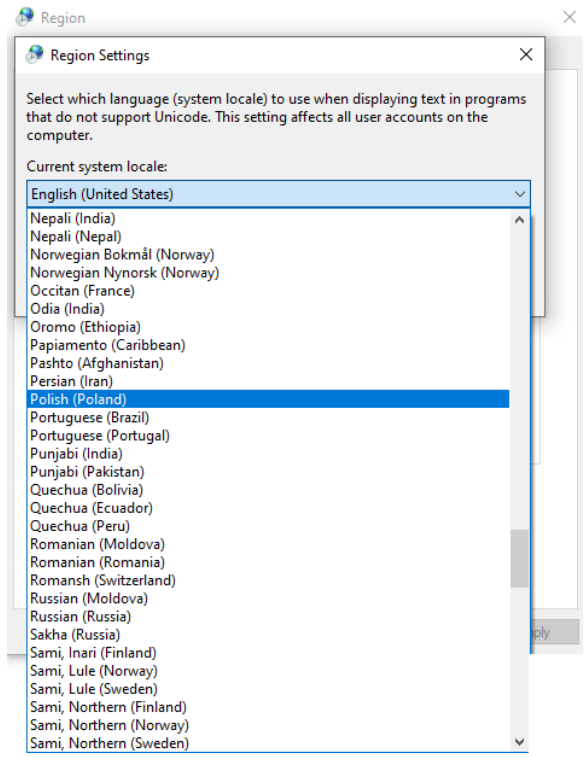

Figure 2. Changing the language for non-Unicode programs - second step

MPDesign Manual

In this section, the step-by-step instructions on how to use the MPDesign are presented. The walkthrough is supplied with screenshots and extensive comments on the results. That gives the user a vast idea of the MPDesign possibilities and benefits of using the tool.

For the purpose of illustrating the intended use of MPDesign, a simple, exemplary scenario has been created. This use case has been designed in such a way that the full capability of the tool can be demonstrated.

The use-case: cheesecake final assembly

The Happy Cheesecake factory produces several flavours of cheesecakes. All of them are composed of a crust base, the main layer of cheese cream and the topping. The base and cheese cream parts are baked together and, once cooled down, are moved to the final assembly line, where the last element of the cheesecake – the topping, is added.

The Happy Cheesecake plant was established in 1956 and, since then, went through several transformations. The recent one concerned the upgrade of the final assembly line. That was done by extending the line with the last two stations and adding the bespoke robotic arm that relieved workers from the tedious job of transferring cheesecakes to a trolley.

Currently, the final assembly line consists of three main stations:

- Decorating station – where the topping is added to the cheesecake. Since the Happy Cheesecake company allows customers to specify the final look of the product, the topping design changes from order to order. Therefore the decorating station has not been automated and requires manual skills to create sophisticated decors on the cheesecake ganache. The station is equipped with all kinds of decorating accessories stored on the tall rack shelf. Before the latest plant transformation, this station was the last station of the production line.
- Quality check station – after cheesecakes are decorated, they have to pass the quality control check. It is done by visual inspection of cheesecakes. The final products have to be identical and compliant with the customer specification. The station is equipped with a PC where the operator confirms that all cheesecakes passed the quality check and, if not, specifies the issue and the number of incorrect cheesecakes. The report is stored in the internal database, and the batch label (specifying the order number, the number of correct cheesecakes and the date) is printed to be attached to the trolley with cheesecakes.
- Dispatch station – in the last station, cheesecakes are transferred from the conveyor belt to a trolley by a custom-built robotic arm. The trolley has to be moved to the cold room as soon as possible to prevent cheesecakes from decaying. The capacity of the trolley corresponds to a minimal cheesecakes order which is 100kg.

The process in the final assembly line can be depicted as follows:

Figure 3. Process model representation of the final assembly in Happy Cheesecake factory.

The following agents are available in the area of the final assembly line:

- John Ricotta – 61 years old employee who recently suffered from a traffic accident, and since then, he has been using a wheelchair. John was just transferred from a different area of the factory, where the corridors and pathways were not adjusted to the wheelchair movements.
- Nadia Sweet – 45 years old enthusiast of graphic designs. Due to her artistic nature and eye for detail, Nadia is a valued operator of the decorating station.
- Chris Sprinkle – 19 years old apprentice who is eager to learn all production methods and techniques.
- "Petit" - an Automated Guided Vehicle (AGV) that is capable of transporting up to 60kg.
- "Grande" - an Automated Guided Vehicle (AGV) that is capable of transporting up to 150kg.

Note: the robotic arm in the Dispatch station is not considered to be an agent for the process, as this machinery is fixed in the production line. Also, it is designed to perform only one action of transporting cheesecakes to the trolley. Therefore, the robotic arm cannot be assigned to any other task.

MPDesign: Main menu

The Main menu of the MPDesign consists of seven tabs presented in Figure 4.

Figure 4. MPDesign: Main menu

In the Tasks tab, the user provides all the information related to the task to be performed in the process. To distinguish between tasks, the unique name, task description, and task type have to be inserted. Required abilities and authorization that are needed to assign the task to an agent, as well as the task inputs and outputs, are collected in this tab.

The Agents tab provides similar functionality of collecting information. However, data inserted here refer to all available agents in the production area and agents' characteristics like abilities and authorizations.

Tabs Abilities, Authorizations and Inputs/Outputs present the collections of predefined lists of those features. It is also possible to modify the lists by removing entries or adding new ones.

The Analysis tab provides the most crucial functionalities. With one click, the processing of provided data is performed. The results of such analysis are presented in this tab as well. It is also possible to export results to a standard MS Excel spreadsheet.

The Warning tab provides a specific type of analysis results. Namely, the points of attention that the user should consider while designing a complete and efficient manufacturing process.

Note: the order of providing the data depends on user preferences. It is also possible to switch between tabs if needed and perform the analysis again after modifying the data.

A detailed description of how to use each tab is presented in the following subsections.

MPDesign: Tasks tab

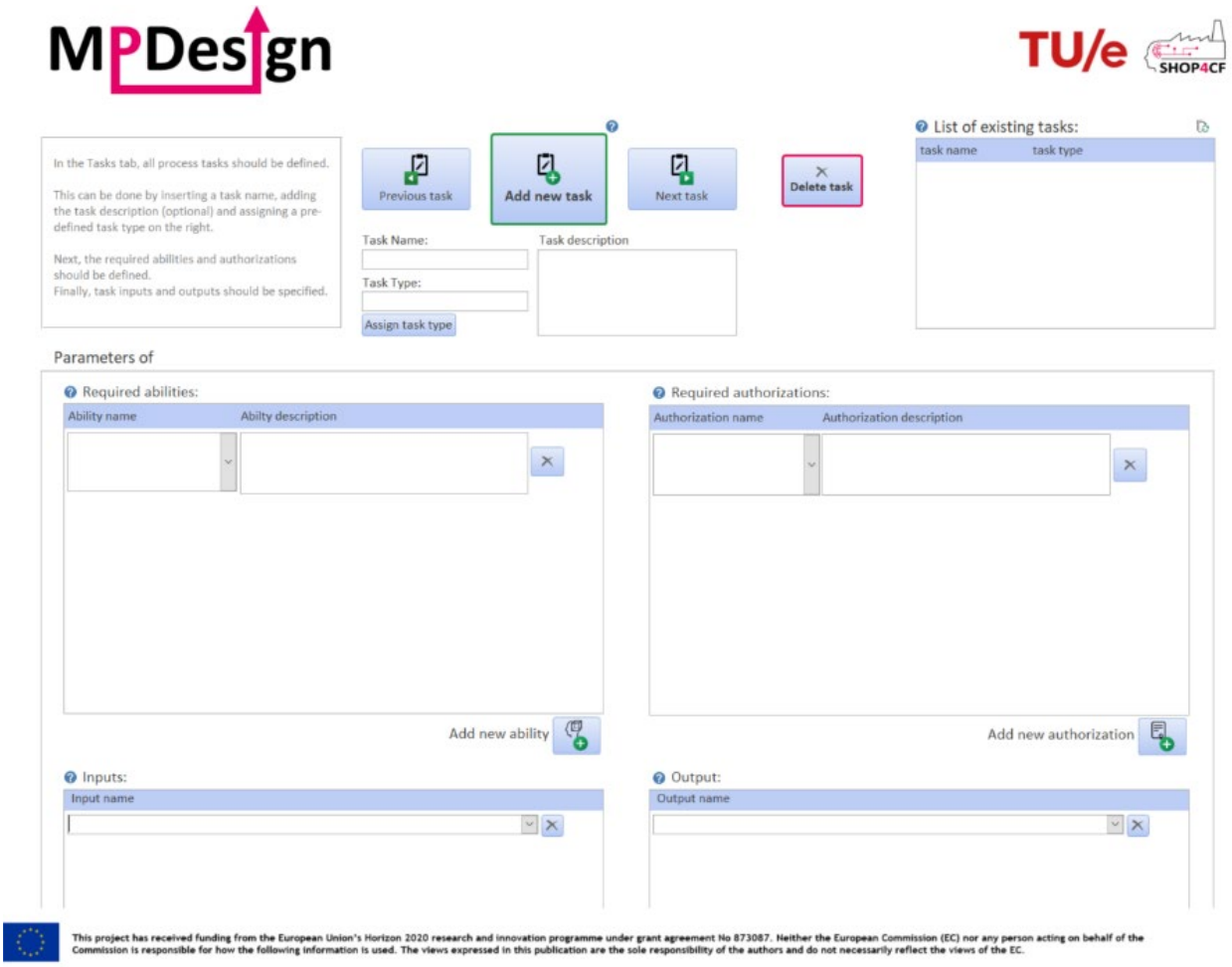

Figure 5. MPDesign: Tasks tab

The ***Tasks*** tab in the main menu is shown in Figure 5. This tab allows the user to insert all the information on tasks in the process that need to be performed.

A task can be created by entering the task name in the empty ***Task Name*** field and assigning a predefined task type by clicking the ***Assign Task Type*** button. The task name should be concise, and the additional description should be provided in the ***Task description*** field. If tasks already exist, the new task can be created by pressing ***Add new task*** button or moving to the end of the existing tasks list by pressing the ***Next task*** button until an empty slot appears. If the existing task is no longer needed, it can be removed from the process by clicking the ***Delete task*** button.
By using the ***Previous task*** and ***Next task*** buttons, the user can go back and forth to other tasks present in the list to introduce modifications if needed.

On the right side of the window, an overview of all the defined tasks is shown. After adding or changing the definition of the task, the ***Refresh*** button must be pressed to update the list of tasks visible in the box.

Below the task definition section, the task parameters can be added. These parameters include *Required abilities* and *Required authorizations* that are necessary to execute the task, as well as the task expected *Inputs* and produced *Outputs*.
The user can choose one of the predefined abilities and authorizations by selecting them from a drop-down list or create a new item by clicking ***Add new ability*** or ***Add new authorization*** buttons. In the latter case, the pop-up window appears (Figure 6), requesting a name and description of a new ability or authorization. The newly created abilities or authorizations are automatically assigned to the task that is currently active in the ***Tasks*** tab.

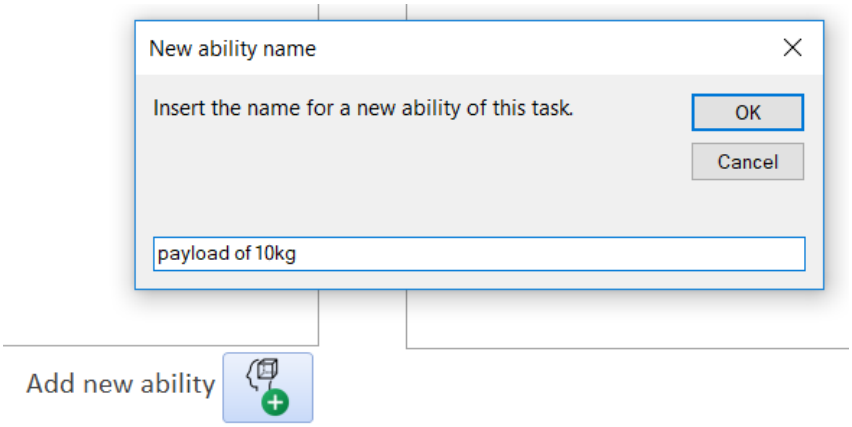

Figure 6. MPDesign: pop-up window to insert a new ability. Below the window the button "Add new ability" calling for this window is visible.

The *predefined* list of authorizations is based on certifications in the manufacturing domain *and can be viewed in the* **Authorizations** *tab.* For the abilities, a distinction is made between the abilities of human agents and robotic agents. *The* human attributes *are structured* into four groups: physical features, abilities without certification and norms. The physical features describe human capabilities, which can be limited due to permanent or temporary impairments (e.g. mobility limitations or injured limbs), making some of the tasks impossible to perform. Modelling those ensures that workers with temporary or permanent disabilities can also be assigned to meaningful and fitting tasks. Furthermore, an initial list of abilities without certification is defined to capture additional, self-declared skills of workers on the shop floor, such as proficiency in using certain software and equipment. Lastly, a set of norms is provided to determine which tasks can be assigned to human operators without breaching any safety and health regulations, like maximum carried weight, time spent in an uncomfortable position, etc. The predefined list of a*bilities* can be viewed in the **Abilities** tab. If the assignment of ability or authorization to a task is not correct, it can be easily removed from the assignment list by pressing the ***Delete*** button, which is visible to the right of the ability or authorization in question (Figure 7).

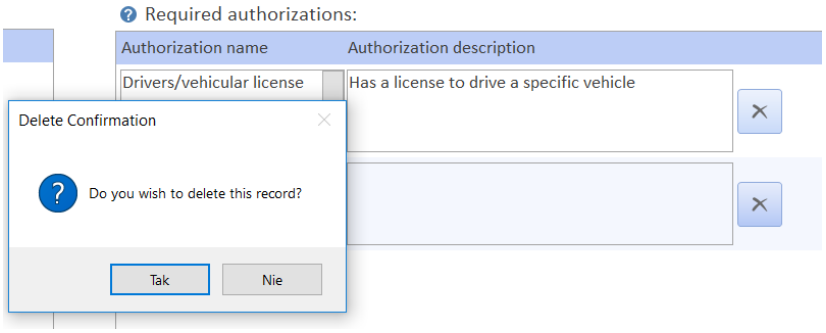

Figure 7. MPDesign: example of an authorization "Drivers/vehicular license" that has been wrongly assigned to a task. Delete button is visible on the right. After pressing the button, the confirmation window appears.

In the final step of defining the task, a set of inputs and outputs must be assigned. The user can choose one of the predefined inputs and outputs by selecting them from a drop-down list (Figure 8) or create the new item by clicking ***Add new input*** or ***Add new output*** buttons. In the latter case, the pop-up window appears, requesting the name of the new input or output. The newly created inputs or outputs are automatically assigned to the task that is currently active in the ***Tasks*** tab.

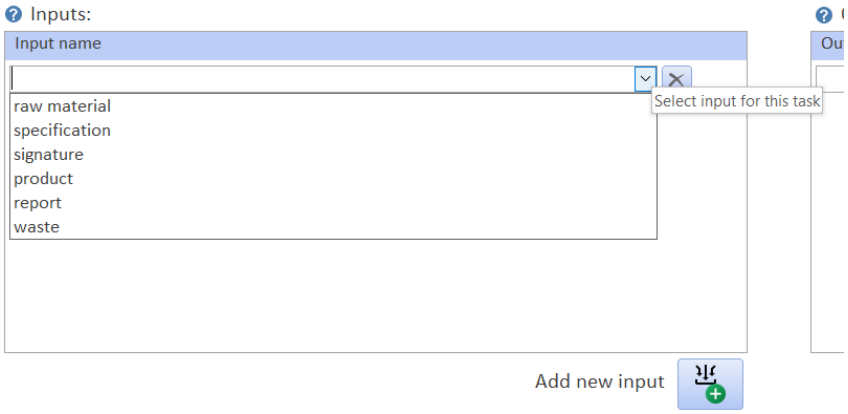

Figure 8. MPDesign: drop-down list of inputs. On the bottom the "Add new input" button is visible.

The inputs and outputs are use case-specific as they depend on what is manufactured in a process. Therefore, each analyzed process requires its own set of inputs and outputs. To make the definition more user-friendly, an exemplary list of inputs and outputs has been provided. However, the list is not, by all means, exhaustive. The predefined list of inputs and outputs can be viewed in the ***Inputs/Outputs*** tab. If the assignment of input or output to a task is not correct, it can be easily removed from the assignment list by pressing the ***Delete*** button, which is visible to the right of the input or output in question (Figure 9).

Figure 9. MPDesign: example of input "raw materials" that has been wrongly assigned to a task. Delete button is visible on the right.

Example: Cheesecake final assembly – task definition

In the scenario, there are three tasks to be defined in the MPDesign. Each task has specific requirements and inputs/outputs to be assigned. Below the summary of all those parameters derived from the use-case description is presented.

Tasks	Required abilities	Required authorizations	Inputs	Outputs
Decorate cheesecake	1) standing position 2) experience in decorating 3) no vision impairment	1) working with food - permission	1) Cheesecakes decoration recipe 2) decorating accessories	1) status report
Check the quality	1) no vision impairment	1) working with food - permission		1) status report 2) batch label
Dispatch cheesecakes	1) transportation of 100kg		1) batch label 2) decoration recipe	

Table 1. The summary of all tasks and the tasks parameters in the Cheesecake scenario

Note:

1) Tasks where the human operator interacts directly with cheesecakes require the "working with food - permission". That requirement is implicit. However, it inherently belongs to the food manufacturing domain.

2) "status report" output of task "Decorate cheesecake" comes from the fact that this task used to be linked to the last station in the process before the transformation. As such, it has been creating the status report on each batch of cheesecakes that has been produced in this station.

Below, screenshots present a complete definition of each task with its parameters in MPDesign.

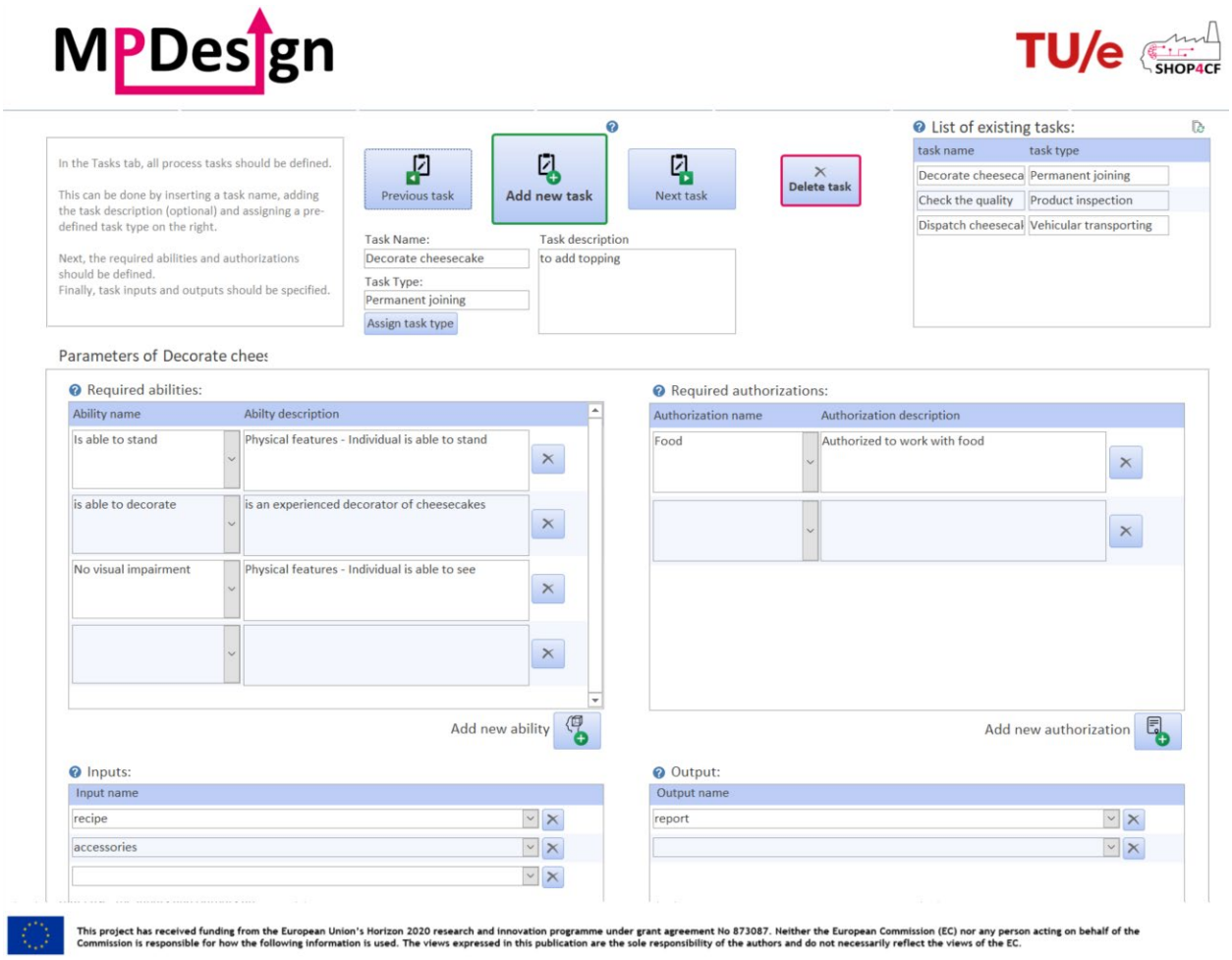

Figure 10. Definition of task: Decorate cheesecake

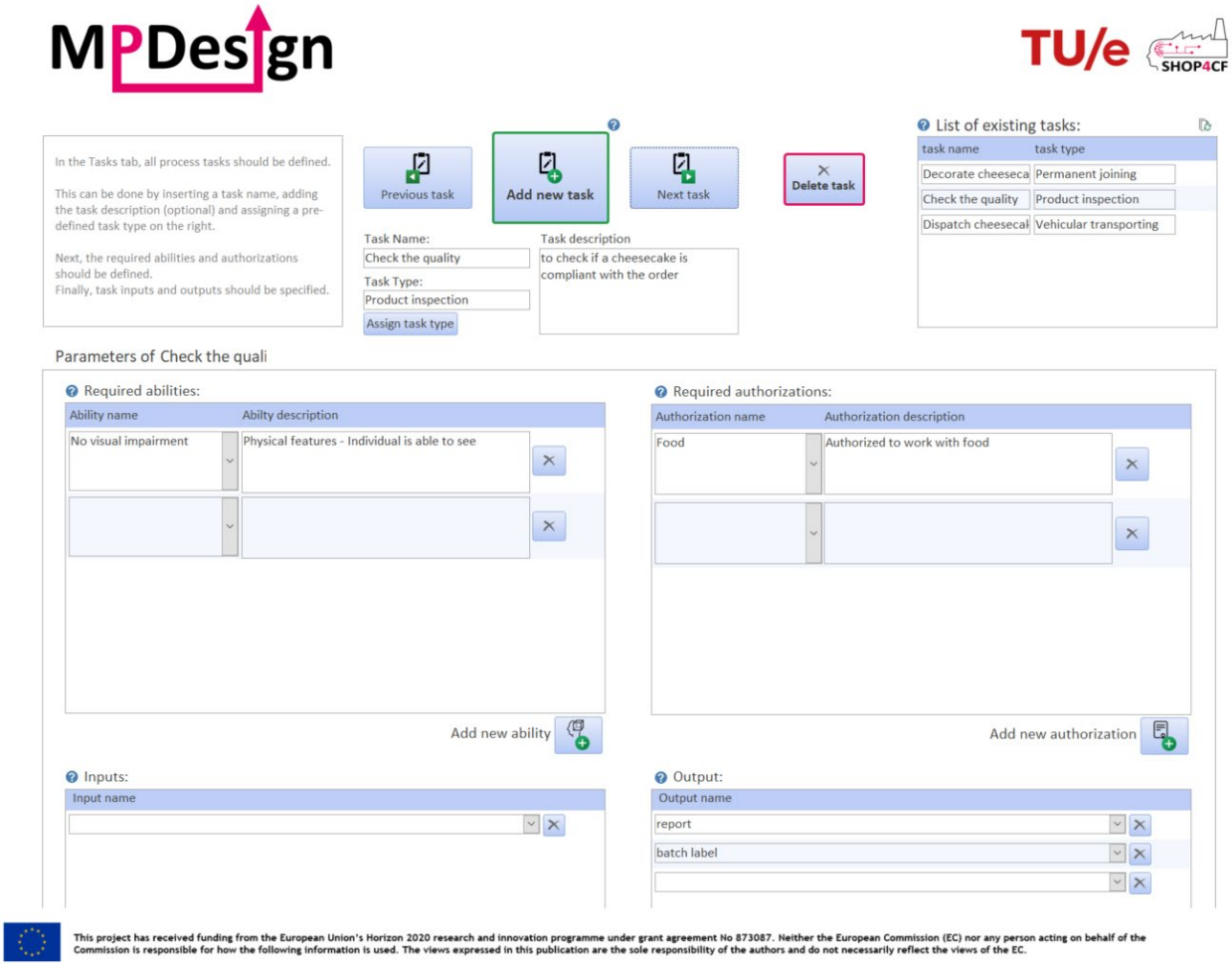

Figure 11. Definition of task: Check the quality

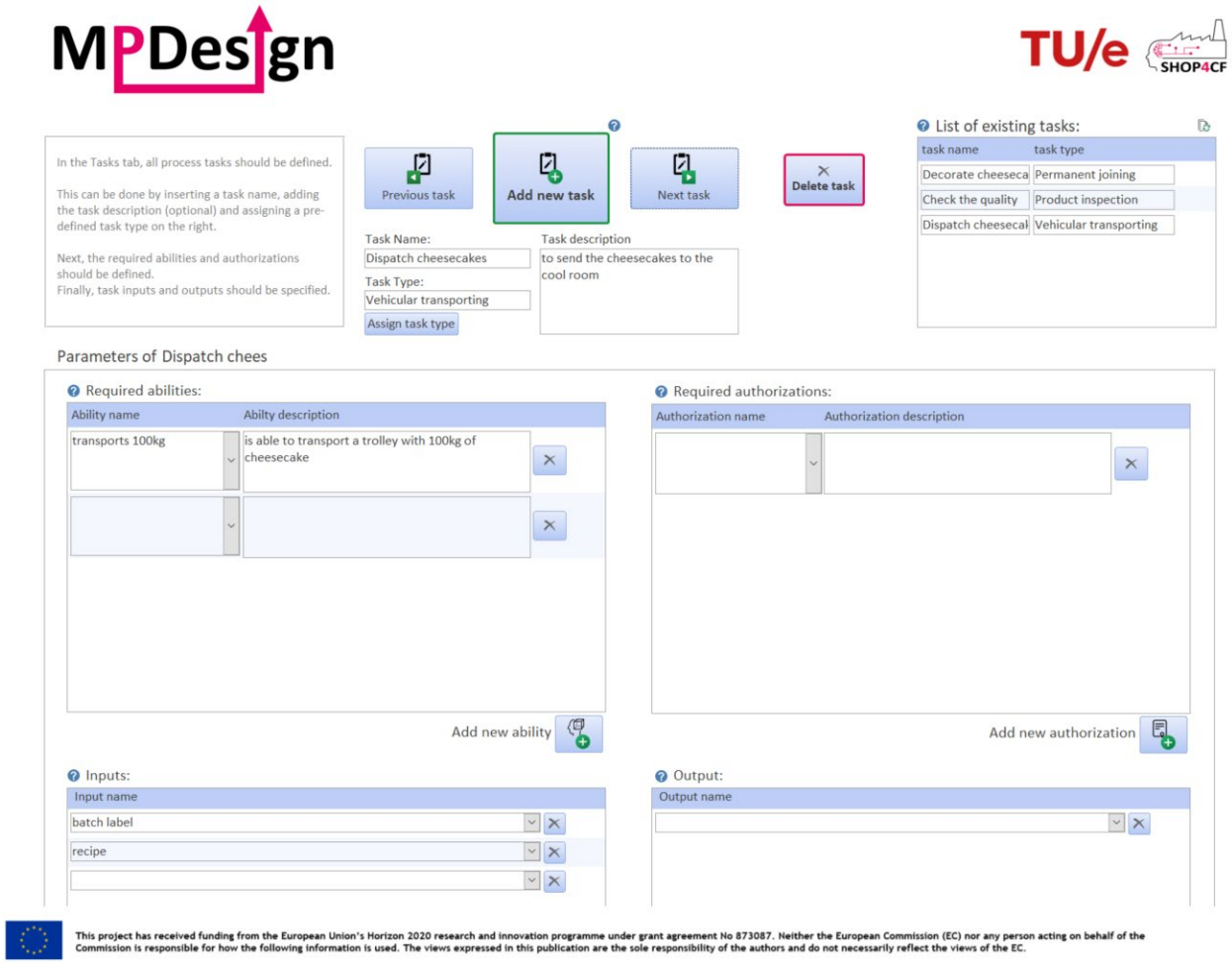

Figure 12. Definition of task: Dispatch cheesecakes

MPDesign: Agents tab

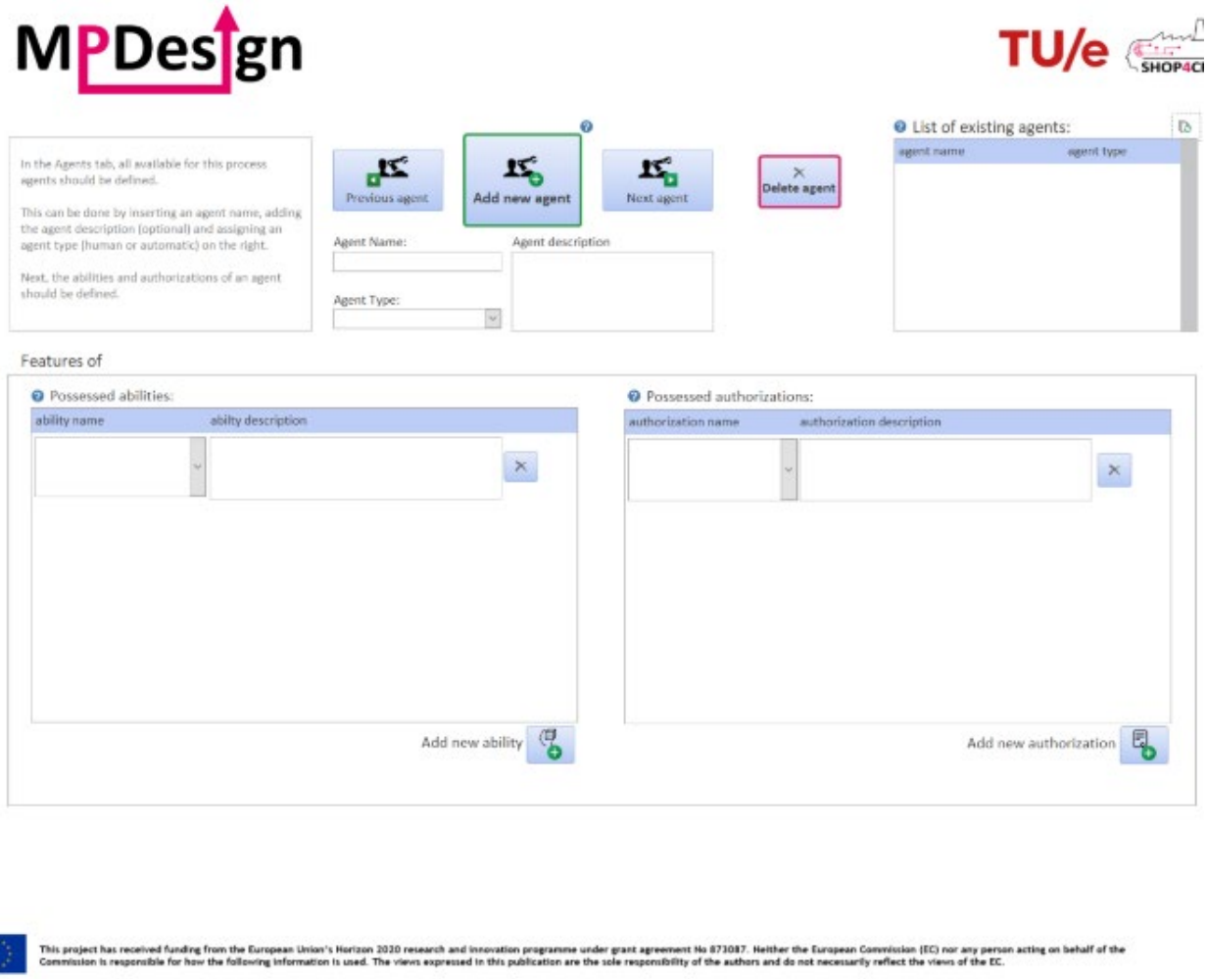

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Figure 13. MPDesign: Agents tab

The ***Agents*** tab from the main menu is shown in Figure 13. This tab allows the user to insert all the information on agents that are available in the manufacturing area under consideration.

An agent can be created by entering the agent name in the empty ***Agent Name*** field and assigning a predefined agent type (human or automatic) by clicking the ***Assign Agent Type*** button. The agent name should be concise, and the additional description should be provided in the ***Agent description*** field. If agents already exist, the new agent can be created by pressing ***Add new agent*** button or moving to the end of the existing agents' list by pressing the ***Next agent*** button until an empty slot appears. If the existing agent is no longer needed, it can be removed from the process by clicking the ***Delete agent*** button.
By using the ***Previous agent*** and ***Next agent*** buttons, the user can go back and forth to other agents present in the list to introduce modifications if needed.

On the right side of the window, an overview of all the defined agents is shown. After adding or changing the definition of the agent, the ***Refresh*** button must be pressed to update the list of agents visible in the box.

Below the agent definition section, the agent parameters can be added. These parameters include *Possessed abilities* and *Possessed authorizations* that reflect agent features and capabilities.
The user can choose one of the predefined abilities and authorizations by selecting them from a drop-down list or create a new item by clicking ***Add new ability*** or ***Add new authorization*** buttons. In the latter case, the pop-up window appears (Figure 14), requesting a name and description of a new ability or authorization. The newly created abilities or authorizations are automatically assigned to the agent that is currently active in the ***Agents*** tab.

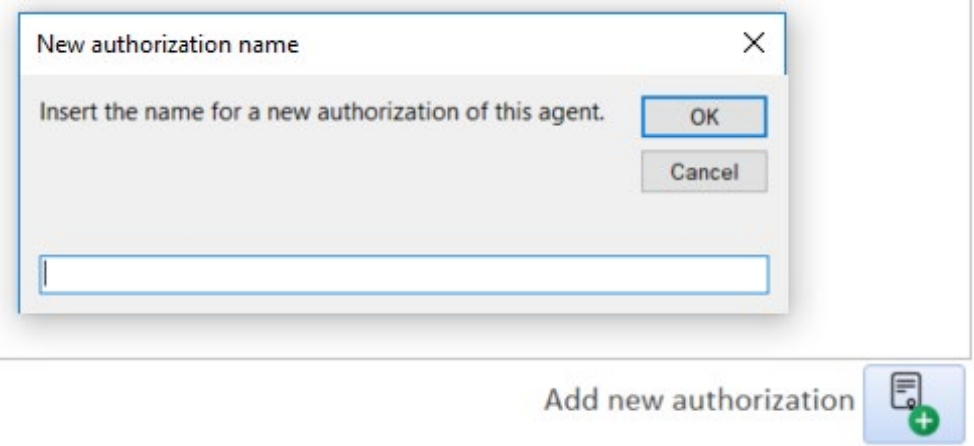

Figure 14. MPDesign: pop-up window to insert new ability of an agent. Below the window the button "add new ability" calling for this window is visible.

The *predefined* list of authorizations is based on certifications in the manufacturing domain *and can be viewed in the* **Authorizations** *tab.* For the abilities, a distinction is made between the abilities of human agents and robotic agents. *The* human attributes *are structured* into four groups: physical features, abilities without certification and norms. The physical features describe human capabilities, which can be limited due to permanent or temporary impairments (e.g. mobility limitations or injured limbs), making some of the tasks impossible to perform. Modelling those ensures that workers with temporary or permanent disabilities can also be assigned to meaningful and fitting tasks. Furthermore, an initial list of abilities without certification is defined to capture additional, self-declared skills of workers on the shop floor, such as proficiency in using certain software and equipment. Lastly, a set of norms is provided to determine which tasks can be assigned to human operators without breaching any safety and health regulations, like maximum carried weight, time spent in an uncomfortable position, etc. The predefined list of a*bilities* can be viewed in the **Abilities** tab. If the assignment of ability or authorization to an agent is not correct, it can be easily removed from the assignment list by pressing the ***Delete*** button, which is visible to the right of the ability or authorization in question (Figure 15).

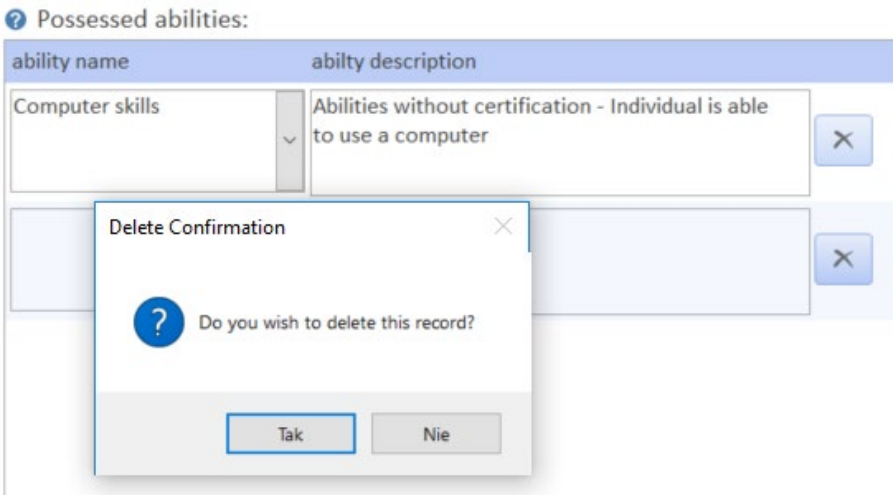

Figure 15. MPDesign: example of an authorization "Drivers/vehicular license" that has been wrongly assigned to a task. Delete button is visible on the right. After pressing the button, the confirmation window appears.

Example: cheesecake final assembly – agent definition

In the scenario, there are five agents to be defined in the MPDesign. Each agent has specific attributes to be assigned. Below the summary of all those parameters derived from the use-case description is presented.

Agent	Possessed abilities	Possessed authorizations
John Ricotta	no vision impairment	Working with food permission
Nadia Sweet	no vision impairment Is able to work standing Is able to decorate	Working with food permission
Chris Sprinkle	no vision impairment Is able to work standing	Working with food permission
“Petit”	is capable of transporting up to 60kg.	
“Grande”	is capable of transporting up to 150kg.	

Table 2. The summary of all agents and the agents parameters in the Cheesecake scenario

Note:

1) All the employees of Happy cheesecake factory that interact directly with cheesecakes have valid “working with food - permission”. That certification is not explicitly stated in the scenario description. However, it inherently belongs to the food manufacturing domain.

Below, screenshots present a complete definition of each agent with its parameters in MPDesign.

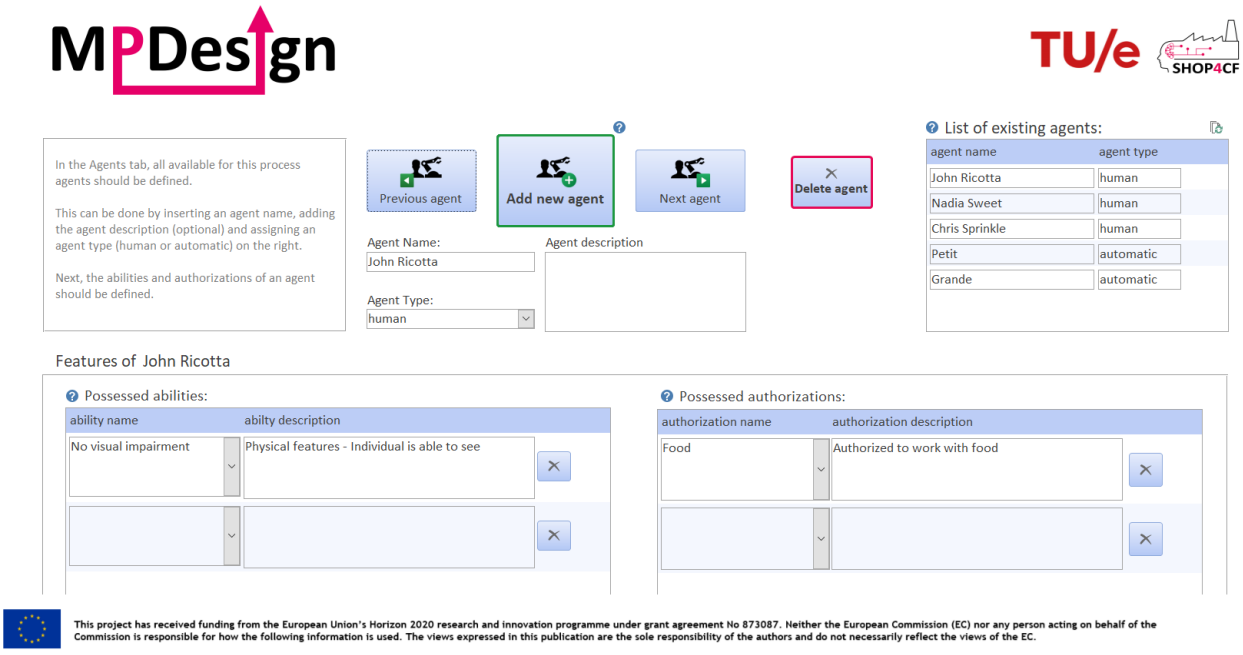

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Figure 16. Definition of agent: John Ricotta

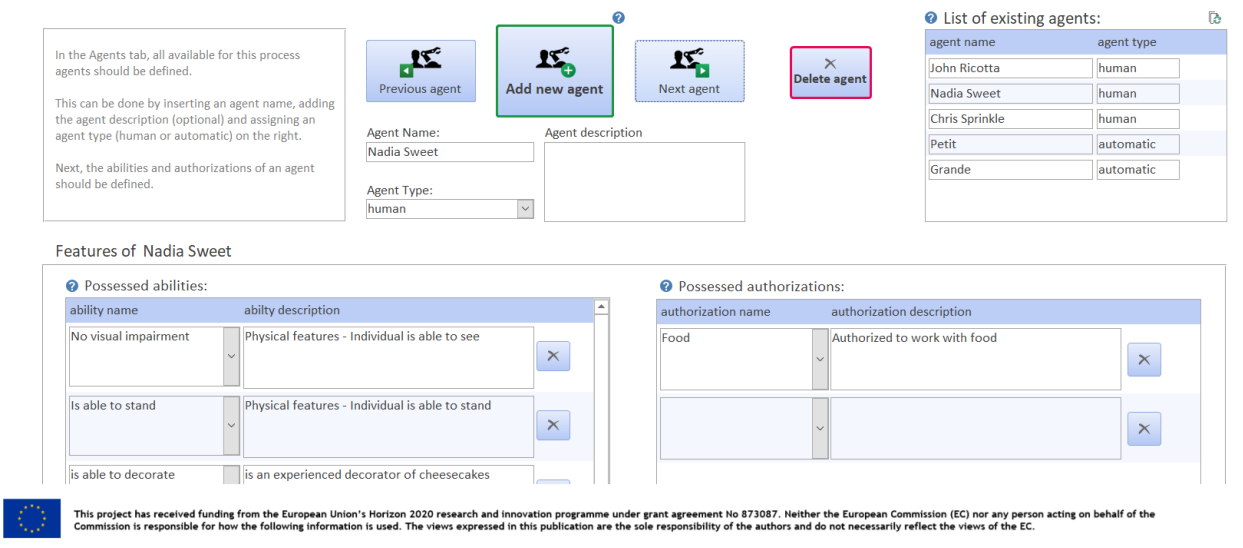

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Figure 17. Definition of agent: Nadia Sweet

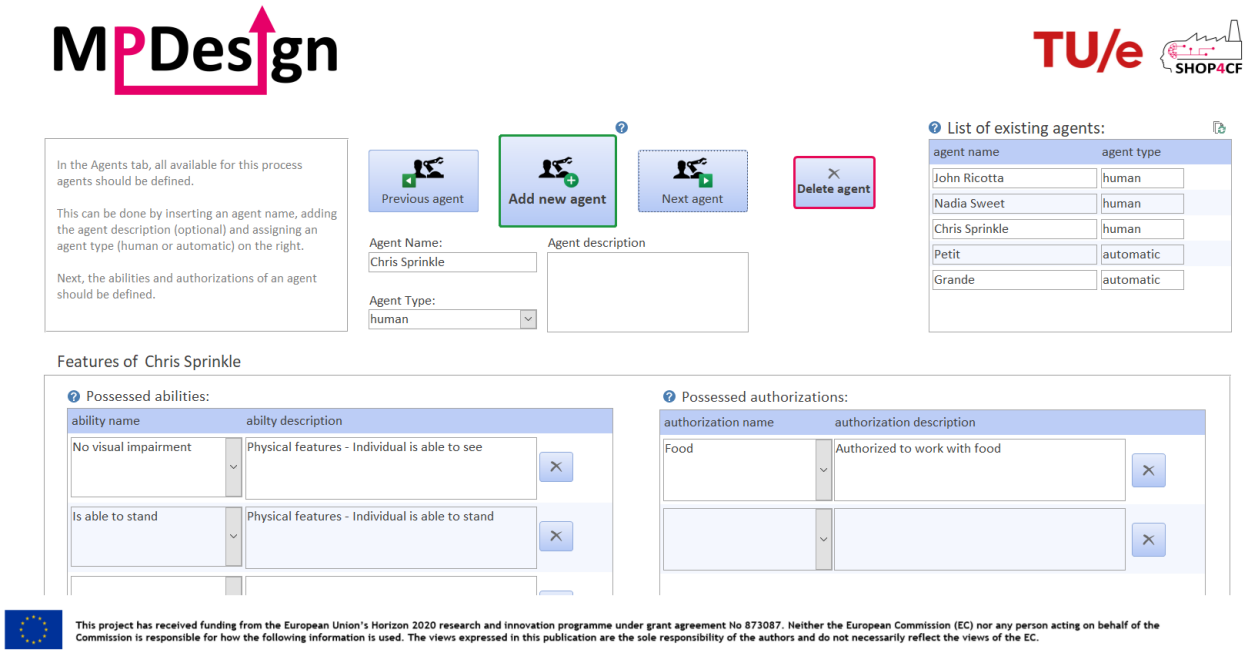

Figure 18. Definition of agent: Chris Sprinkle

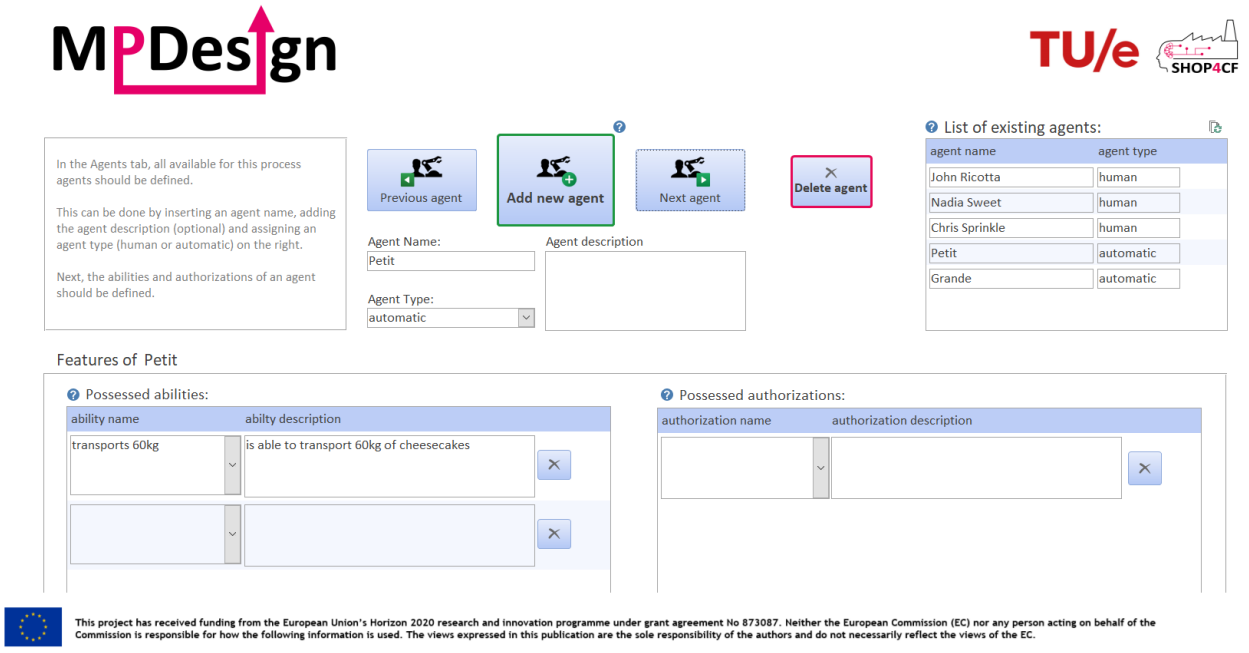

Figure 19. Definition of agent: Petit

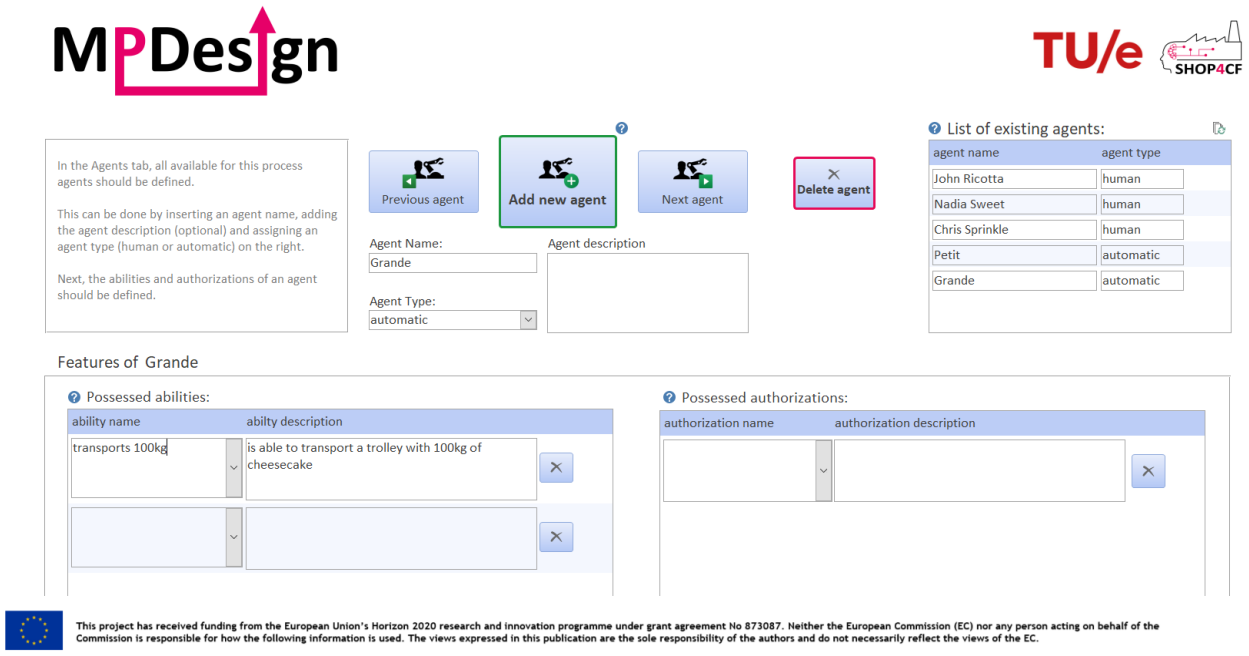

Figure 20. Definition of agent: Grande

MPDesign: Abilities tab

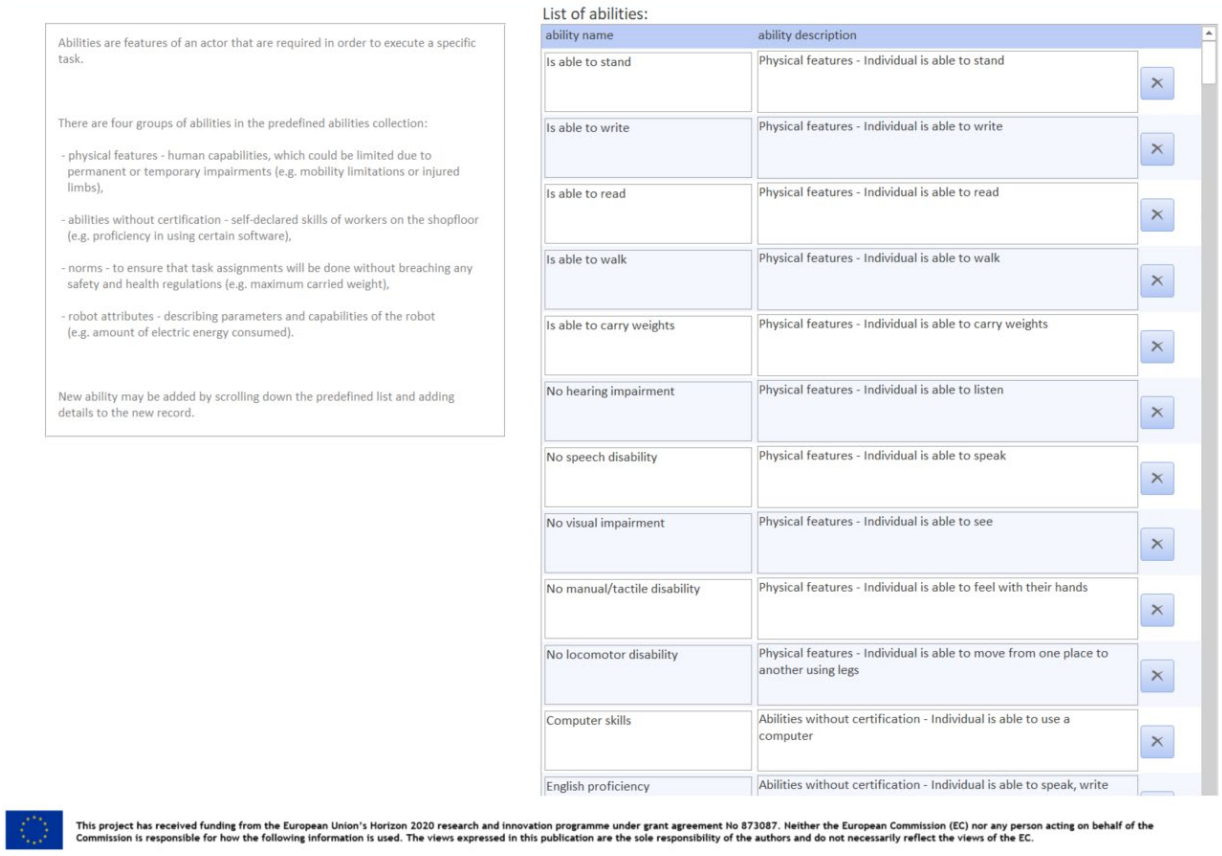

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Figure 21. MPDesign: Abilities tab

The ***Abilities*** tab (Figure 21) presents the list of all predefined features of an actor that are required in order to execute a specific task.

There are four groups of abilities in the predefined abilities collection:

- physical features - human capabilities, which could be limited due to permanent or temporary impairments (e.g. mobility limitations or injured limbs),
- abilities without certification - self-declared skills of workers on the shop floor (e.g. proficiency in using certain software),
- norms - to ensure that task assignments will be done without breaching any safety and health regulations (e.g. maximum carried weight),
- robot attributes - describing parameters and capabilities of the robot (e.g. amount of electric energy consumed).

New ability may be added by scrolling down the predefined list and adding details to the new record. The ability can be easily removed from the list by pressing the ***Delete*** button, which is visible to the right of the ability in question.

Note: All the abilities defined by the user in the ***Tasks*** or ***Agents*** tab are also presented here as a part of the ability collection.

MPDesign: Authorizations tab

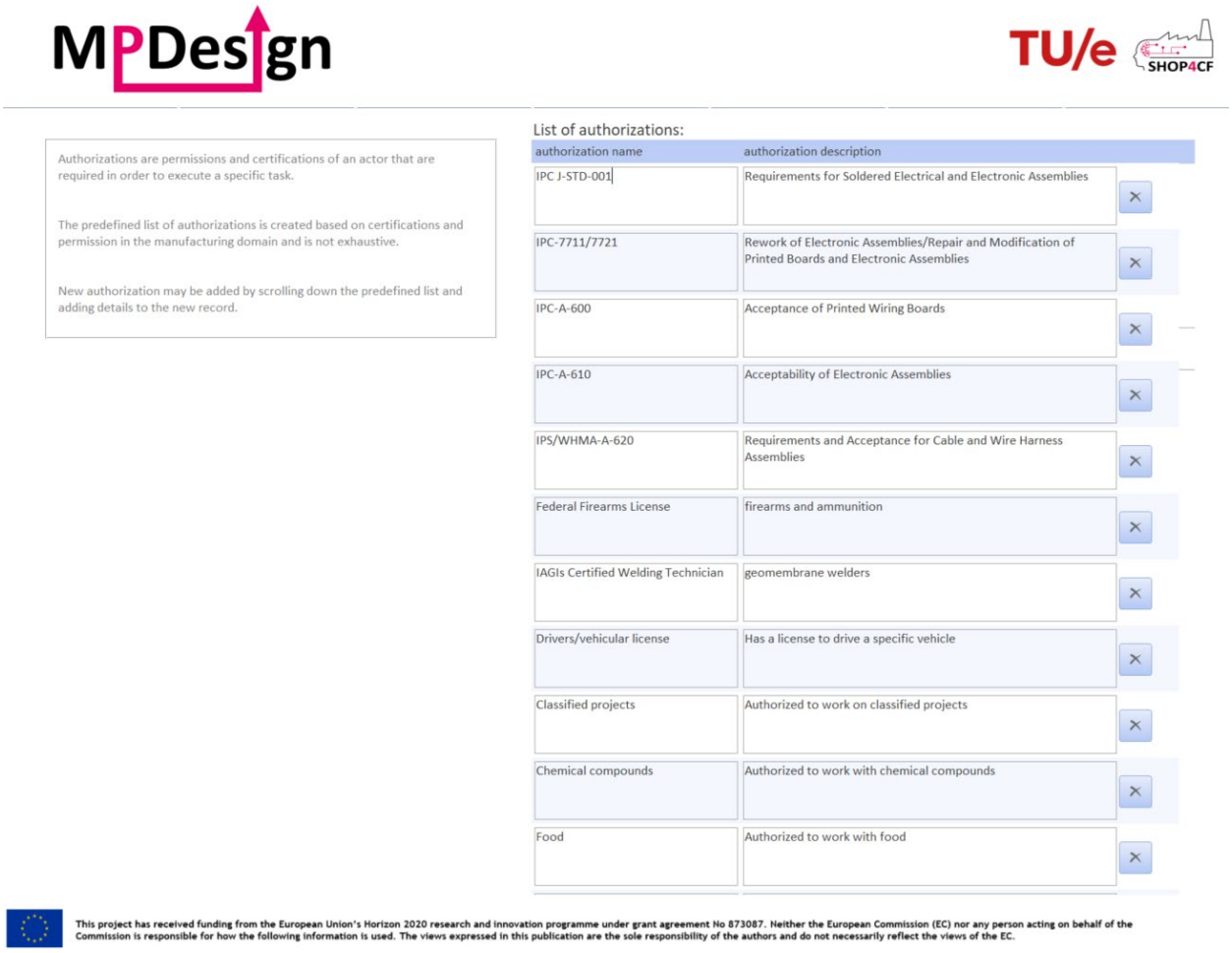

Figure 22. MPDesign: Authorization tab

The ***Authorizations*** tab (Figure 22) presents the list of all predefined permissions and certifications of an actor that are required in order to execute a specific task.
The predefined list of authorizations is created based on certifications and permission in the manufacturing domain and is not exhaustive.
New authorization may be added by scrolling down the predefined list and adding details to the new record. The authorization can be easily removed from the list by pressing the ***Delete*** button, which is visible to the right of the authorization in question.

Note: All the authorization defined by the user in the ***Tasks*** or ***Agents*** tab are also presented here as a part of the authorization collection.

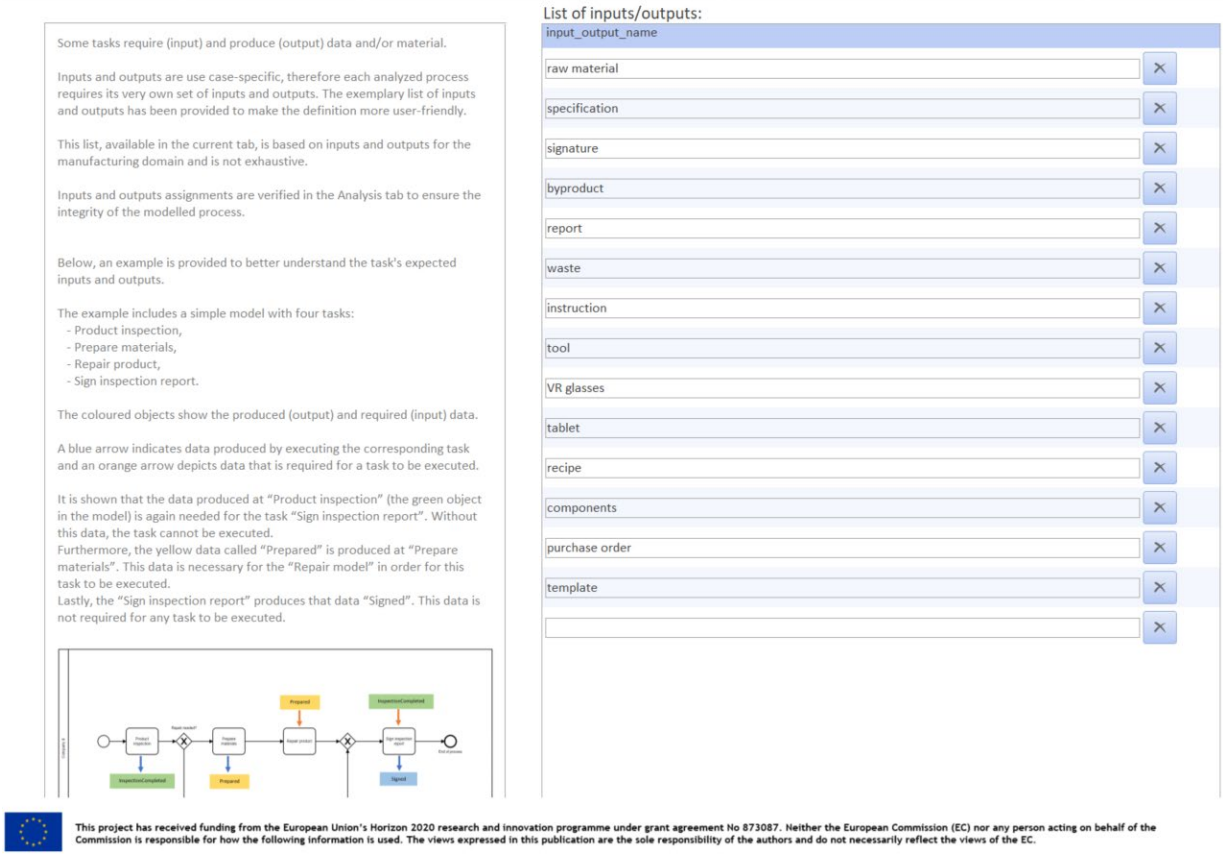

Figure 23. MPDesign: Inputs/Outputs tab

Some tasks require (input) and produce (output) data and/or material. Inputs and outputs are use case-specific. Therefore each analysed process requires its very own set of inputs and outputs. The exemplary list of inputs and outputs has been provided in ***Inputs/Outputs*** tab (Figure 23) to make the definition more user-friendly. This list is based on inputs and outputs for the manufacturing domain and is not exhaustive.

New inputs/outputs may be added by scrolling down the predefined list and adding details to the new record. The input/output can be easily removed from the list by pressing the ***Delete*** button, which is visible to the right of the input/output in question.

Note: All the inputs or outputs defined by the user in the ***Tasks*** tab are also presented here as a part of inputs/outputs collection.

MPDesign: Analysis tab

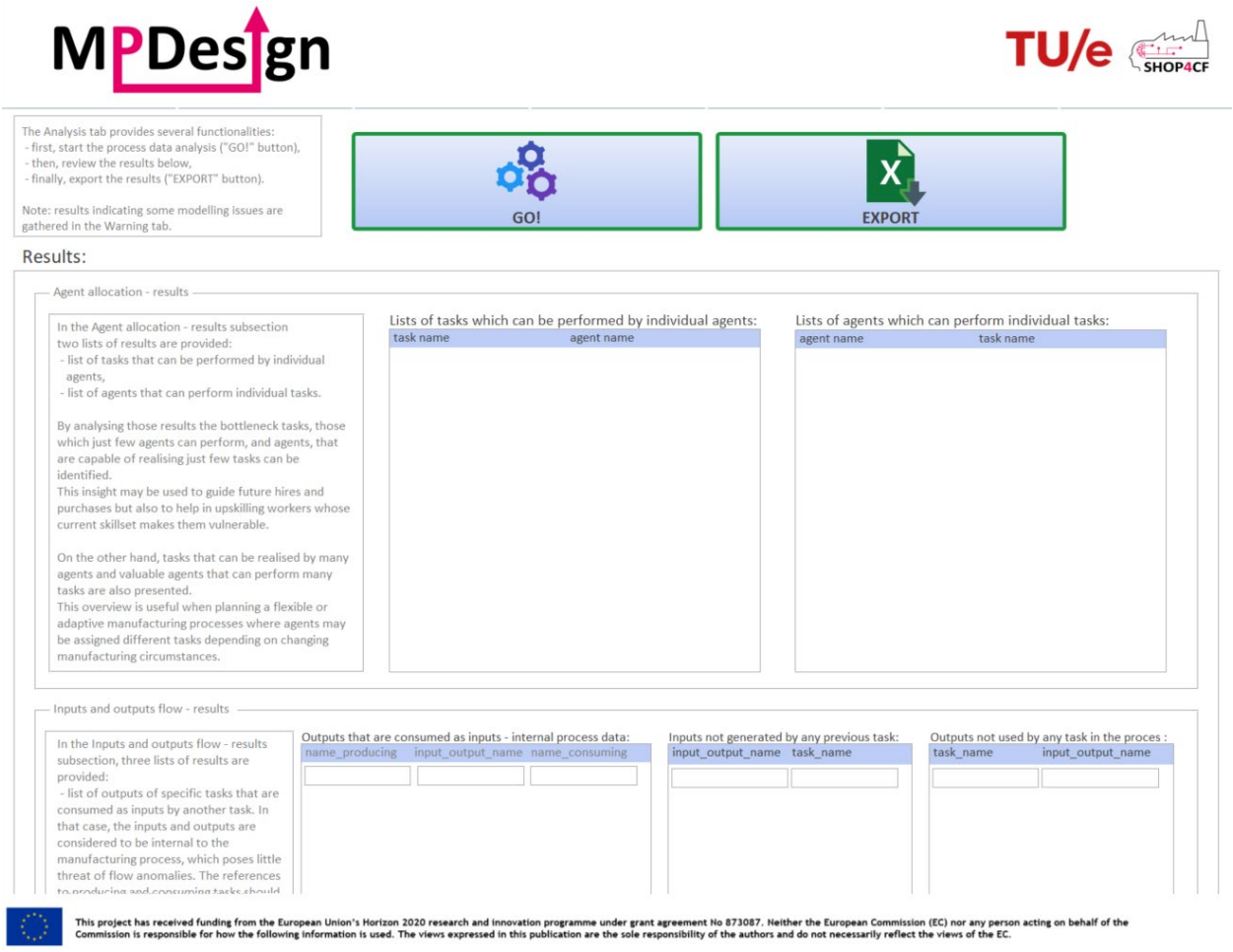

Figure 24. MPDesign: Analysis tab

The ***Analysis*** tab (Figure 24) provides several functionalities:

- process data analysis can be performed by pressing the ***GO!*** button,
- the results of the data processing are presented below,
- the export of the results to a standard MS Excel file can be done by clicking the ***EXPORT*** button.

The results are presented in two subsections:

- the *Agent allocation - results* subsection,
- the *Inputs and outputs flow - results* subsection.

In the *Agent allocation - results* subsection, two lists of results are provided:

- list of tasks that can be performed by individual agents,
- list of agents that can perform individual tasks.

By analysing those results, the bottleneck tasks, those which just few agents can perform, and agents, that are capable of realising just few tasks can be identified. This insight may be used to guide future hires and purchases but also to help in upskilling workers whose current skillset makes them vulnerable. On the other hand, tasks that can be realised by many agents and valuable agents that can perform many tasks

are also presented. This overview is useful when planning flexible or adaptive manufacturing processes where agents may be assigned different tasks depending on changing manufacturing circumstances.

In the *Inputs and outputs flow - results* subsection, three lists of results are provided:
- list of outputs of specific tasks that are consumed as inputs by another task. In that case, the inputs and outputs are considered to be internal to the manufacturing process, which poses little threat of flow anomalies. The references to producing and consuming tasks should be checked.
- list of inputs which are not generated by any previous task (which need to be provided as external resources). Those inputs are typically produced as an outcome of other processes. The main risk is that this external input has not been yet produced, and the analysed process is kept on hold. The synchronisation between processes is an important challenge.
- list of outputs not used by any task in the process. Those outputs should correspond to the process's final products but may also be a redundant subproduct not used by any other process in the organisation. Redundant data or material results in inefficiency of the process or generating costly waste.

The ***Export*** button allows for exporting the results to the Excel spreadsheet. The name and location of the document can be determined as shown in the Figure 25.

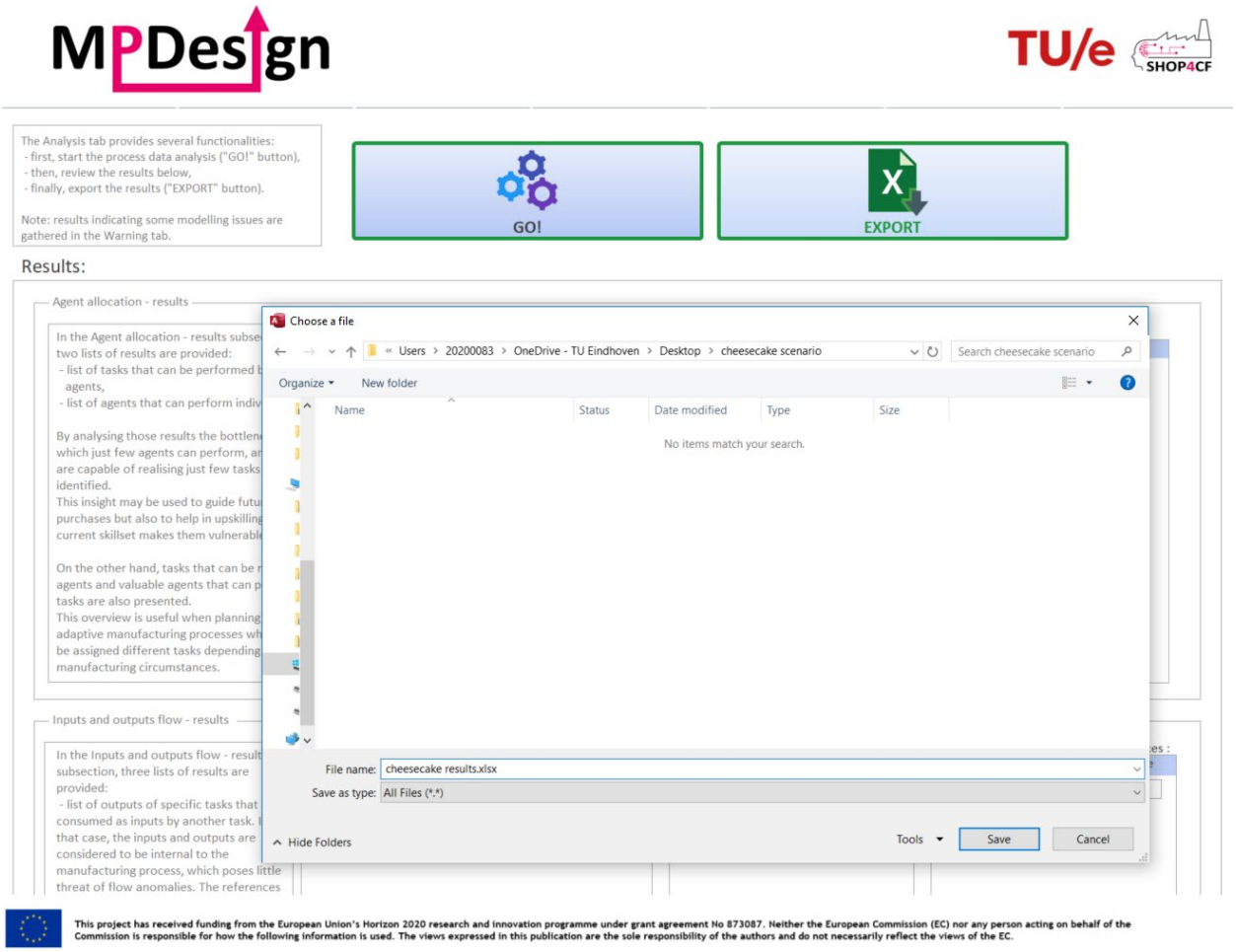

Figure 25. MPDesign: exporting the results

The exported file consists of the following tabs:

- tbl_ability – contains collection of all defined abilities
- tbl_agent – contains collection of all defined agents
- tbl_agent_type – contains collection of all defined agent types
- tbl_agent_ability – contains a list of all assignments of an ability to an agent
- tbl_agent_authorization – contains a list of all assignments of an authorization to an agent
- tbl_agents_who_can_do_tasks – ANALYSIS RESULTS: list of agents that can perform individual tasks
- tbl_agents_without_tasks – ANALYSIS RESULTS: those tasks possess requirements that cannot be fulfilled by any agent
- tbl_authorizations – contains collection of all defined authorizations
- tbl_input – contains a list of all assignments of an input to a task
- tbl_input_and-outputs_names – contains collection of all defined inputs/outputs
- tbl_input_external – ANALYSIS RESULTS: list of inputs which are not generated by any previous task
- tbl_input_multiple – ANALYSIS RESULTS: identical inputs used by more than one task
- tbl_input_output_internal – ANALYSIS RESULTS: list of outputs of specific tasks that are consumed as inputs by another task
- tbl_output – contains a list of all assignments of an output to a task
- tbl_output_external – ANALYSIS RESULTS: list of outputs not used by any task in the process
- tbl_output_multiple – ANALYSIS RESULTS: identical outputs generated by more than one task
- tbl_task – contains collection of all defined tasks
- tbl_task_type – contains collection of all defined task types
- tbl_task-ability – contains a list of all assignments of an ability to a task
- tbl_task-authorization – contains a list of all assignments of an authorization to a task
- tbl_tasks_doable_by_agent – ANALYSIS RESULTS: list of tasks that can be performed by individual agents
- tbl_tasks_without_agents – ANALYSIS RESULTS: those agents have skillsets or parameters that don't match any task in the analysed process

Example: cheesecake final assembly – analysis results

The results of the data analysis for the use case of “cheesecake final assembly” are presented in Figure 26 and Figure 27.

Agent allocation – results (Figure 26) subsection presents which agents can be assigned to which tasks. By analysing the results, the following conclusions can be made:

- “Check the quality” task can be done by all human agents. That means that this task poses no risk of being uncompleted due to agent shortage.
- “Decorate cheesecake” and “Dispatch cheesecake” tasks can be performed by just one agent each. Perhaps upskilling another human operator (“Decorate cheesecake”) and purchasing a new AGV capable of transporting 100kg (“Dispatch cheesecakes”) could prevent the manufacturing process from being stuck in case the existing agent is not available. This lack of disposition may

occur due to illness or time off (human agents), as well as malfunction or maintenance activities (automatic agents).

- "John Ricotta" and "Chris Sprinkle" have skillsets that fulfil the requirements of just one task. Transferring those agents to different processes that better fit the operators' capabilities or upskilling them may bring more flexibility to the production planning.

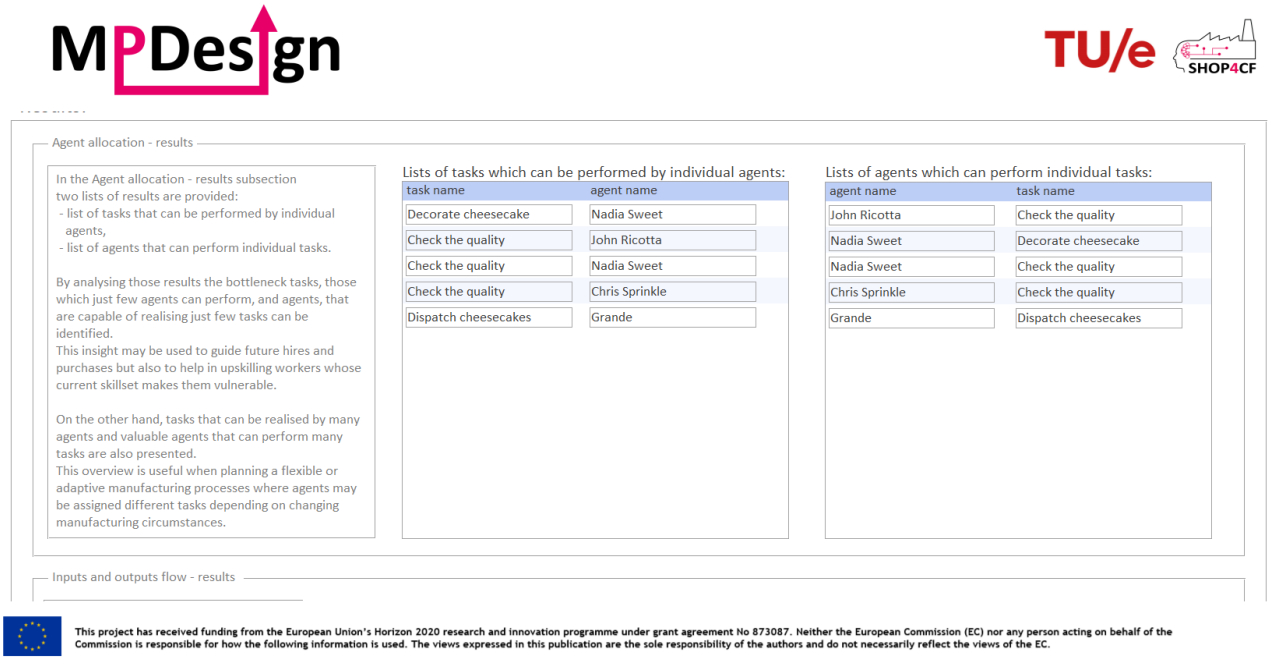

Figure 26. Agent allocation – results

Inputs and outputs flow – results (Figure 27) subsection provides insight on where inputs and outputs are generated and consumed. By analysing the results, the following conclusions can be made:

- "batch label" is the only internal (to the process) item. It is produced by "Check the quality" task and consumed by the "Dispatch cheesecakes" task. That means the "batch label" is not redundant or doesn't depend on other processes.
- There are two items[3] that are input to tasks but haven't been produced by any previous task in this process. This fact indicates that "accessories" and "recipe" are delivered to the process by external tasks. The issue of synchronization between processes may occur. Therefore, the user should analyse the related manufacturing process that delivers discussed items, and make sure the items are available for the cheesecake final assembly process on time.
- "Report"[4] output is not consumed by any other task in this process. That means the "report" should be utilised by a different process in the organisation. The user should check whether this is the case. If not, unnecessary outputs should be eliminated as they cause process inefficiency and costly waste.

[3] The repetition of the „recipe" item is discussed in the Warning tab section.
[4] The repetition of the „report" item is discussed in the Warning tab section.

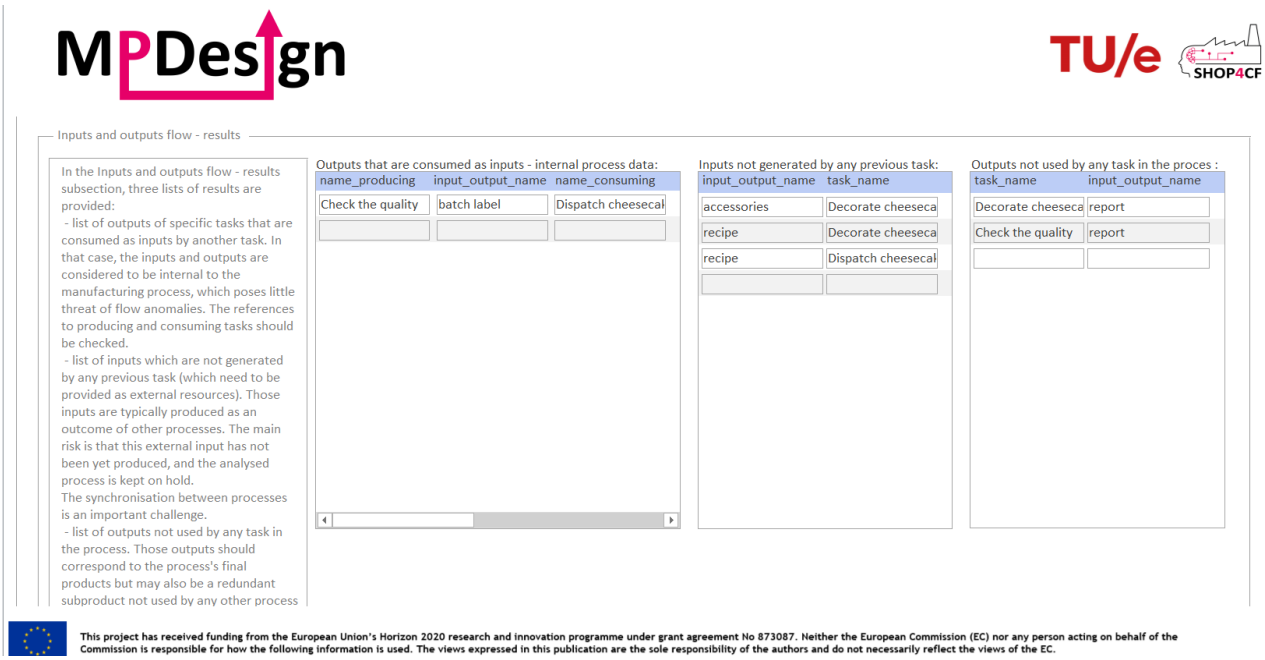

Figure 27. Inputs and outputs flow - results

MPDesign: Warnings tab

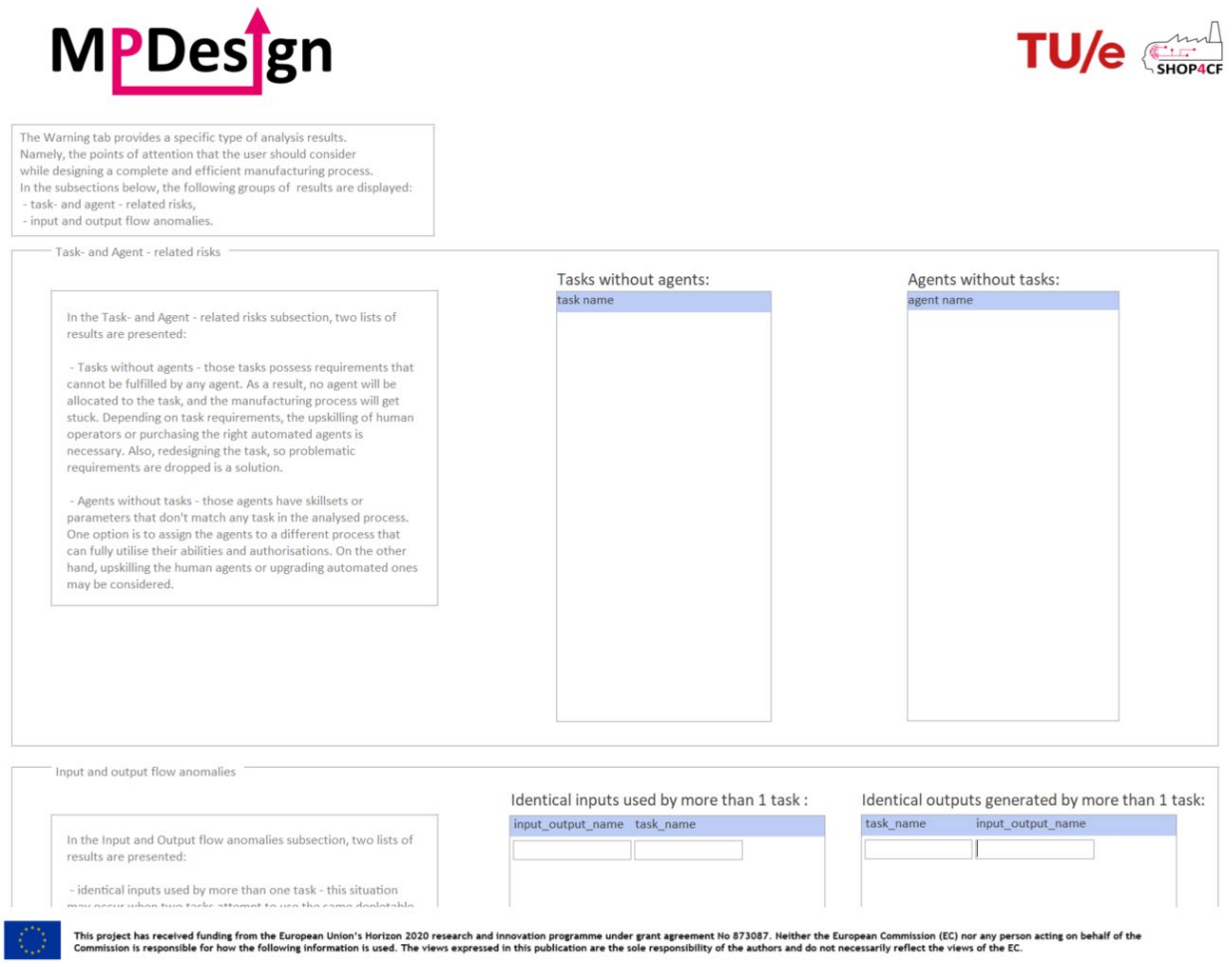

Figure 28. MPDesign: Warnings tab

The ***Warning*** tab (Figure 28) provides a specific type of analysis results. Namely, the points of attention that the user should consider while designing a complete and efficient manufacturing process. In the subsections, the following groups of results are displayed:

- *task- and agent - related risks*,
- *input and output flow anomalies*.

In the *Task- and Agent - related risks* subsection, two lists of results are presented:

- Tasks without agents - those tasks possess requirements that cannot be fulfilled by any agent. As a result, no agent will be allocated to the task, and the manufacturing process will get stuck. Depending on task requirements, the upskilling of human operators or purchasing the right automated agents is necessary. Also, redesigning the task, so problematic requirements are dropped is a solution.
- Agents without tasks - those agents have skillsets or parameters that don't match any task in the analysed process. One option is to assign the agents to a different process that can fully utilise their abilities and authorisations. On the other hand, upskilling the human agents or upgrading automated ones may be considered.

In the *Input and Output flow anomalies* subsection, two lists of results are presented:

- identical inputs used by more than one task - this situation may occur when two tasks attempt to use the same depletable resource, or the inputs are in fact, different (e.g. two different recipes). However, they were labelled in the process in the same way, therefore from the process perspective, they are one and the same item.
- identical outputs generated by more than one task -that case may happen if the process has been modified and some residual outputs of the previous process are still produced, however, they are no longer needed by this or any other process. This situation may lead to contradicting output information or redundancy in process outcomes (e.g. two tasks produce the final report. One task is the actual last task in the process, producing a report on the entire manufacturing history of the product. The other task was the final step before the process extension. Hence, in the current situation, the report from this task includes only part of the manufacturing information.)
- The other possibility is that two different outputs were named in the same way, therefore, from the process perspective, they are one and the same item.

Example: cheesecake final assembly – warnings

Figure 29 and Figure 30 presents the points of attention that user should solve in order to achieve the correct and optimised process model.

Task- and Agents – related risks (Figure 29) subsection answers the questions of which agent is not used in the process and which task cannot be finished due to lack of eligible agents. By analysing the results, the following conclusions can be made:

- All tasks can be completed by at least one agent. That means that process is in no danger of being unfinished.
- “Petit” agent is never used in the process. Transferring the agent to different, more suitable process or upgrading the agent will make “Petit” useful. Underutilisation of resources is the reason why the organisation fails to generate the desired return of investment.

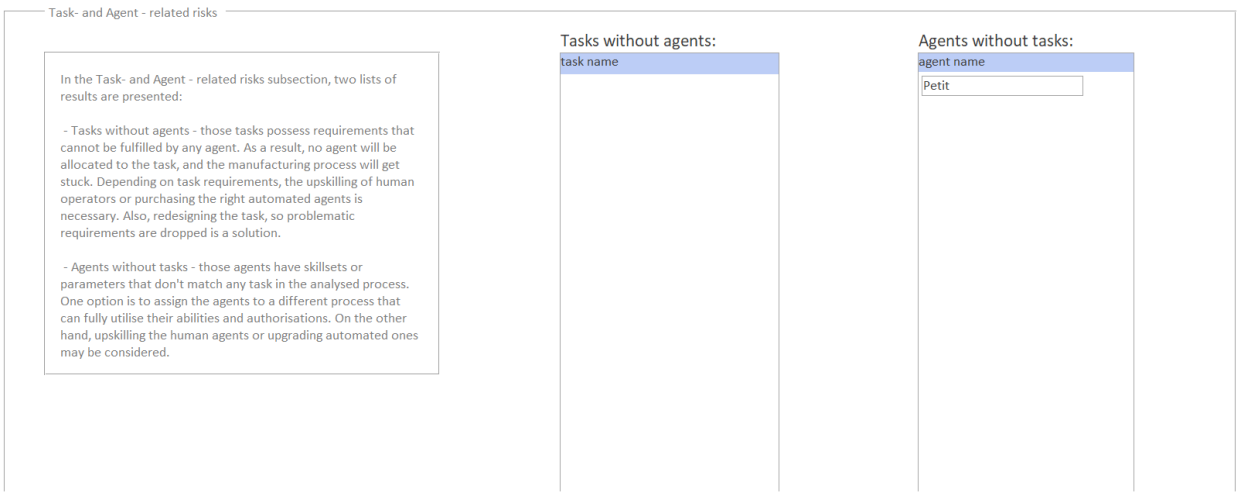

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Figure 29. Task- and Agent- related risks

Input and output anomalies (Figure 30) subsection highlights the issues with input/output flow. By analysing the results, the following conclusions can be made:

- "recipe" item is required as an input for two different tasks. After careful evaluation of tasks requirements, it turns out that "Dispatch cheesecakes" task was incorrectly defined, and the "recipe" input is not needed for this task to be completed.
- Two tasks produce the same output - "Report". In that case, both reports may contain contradicting information. "Decorate cheesecake" task produces the report stating a total number of decorated cakes, while "Check the quality" task reports the number of cakes that were correctly decorated. It is likely that those two numbers are not equal. The case of contradicting information leads to misinterpretation and faulty outcomes (e.g. failed order).

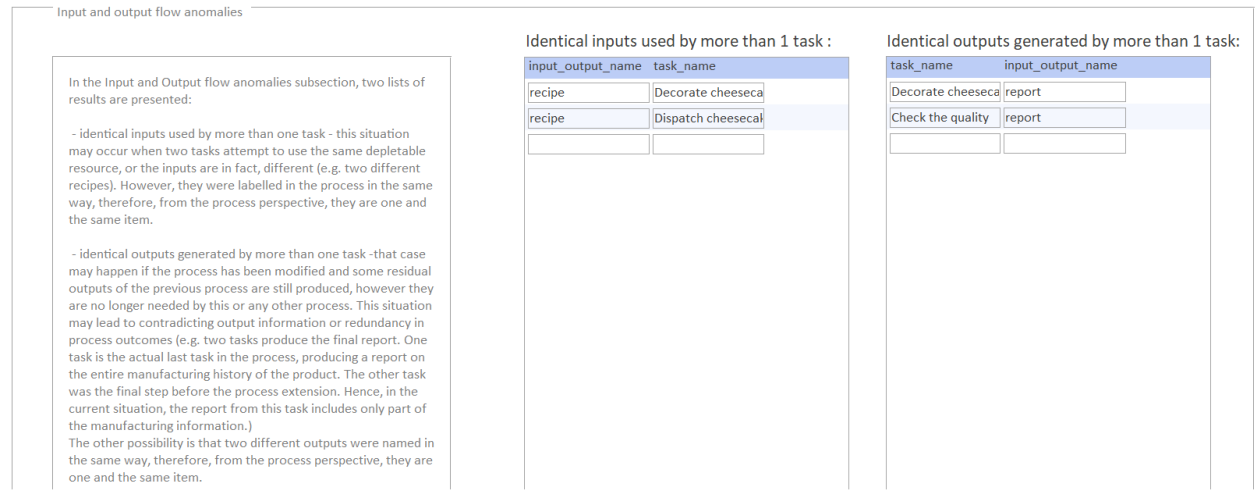

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Figure 30. Input and output flow anomalies