

# PROJECT FINAL REPORT

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## 4.1 Final publishable summary report

### 4.1.1 Executive summary

**Small and medium sized companies** are an essential part of the European maritime economy. They provide a large number of jobs in maritime regions and beyond and successfully serve specific markets in the new build and repair sector.

The entire maritime sector is facing increasingly tough global competition as well as new challenges with regard to product performance and reduced environmental impact. Unlike larger yards, which have successfully specialized in high-value added niche markets and corresponding production processes, small shipyards need to react flexibly and quickly to varying market opportunities. Due to lacking financial and personal resources, limited access to information, expertise and technologies, and other factors, production processes in small and medium sized shipyards often bear significant improvement potentials.

To exploit those potentials, small and medium sized shipyards need technical solutions, skills and business models, which fit their specific needs.

The **SMARTYards project** aimed to improve the productivity of European small and medium sized shipyards and their partners in the process chain by

- including them and their regional maritime clusters in a **Europe wide network**, which facilitates information exchange, access to specific technologies and expertise, and encourages cooperation with researchers and experts from other small and large shipyards;
- Developing and demonstrating **smart solutions**, which are not necessary high-end technology, but which are tailored to the specific needs and requirements of small and medium sized companies.

**Smart solutions** in the understanding of the project consortium need to be simple, flexible, affordable and robust. They need to be integrated into specific shipyard processes in an optimal way, ensuring the largest possible impact for the user. Smart solutions require technologies and equipment, but also corresponding skills and adapted business models, such as cooperation to increase economies of scale. The SMARTYards solutions catalogue presents some of those solutions for typical shipbuilding processes.

**SMARTYards prototypes** were developed specifically for and with end-user companies. After being tested and validated on site.



#### 4.1.2 Project context and objectives

The project “Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards (SMARTYards)” was performed in a consortium of 17 partners from nine European countries in the period October 2013 – September 2016.

While the permanent improvement of shipyard business processes, skills and technologies is a challenge for the entire European shipbuilding industry, small and medium sized (SME) shipyards face specific challenges. Limited financial capabilities and resources reduce their possibilities to invest in new technologies and production facilities. The comparably small scale of financial as well as production turnover reduces the economic feasibility of single purpose automation. Limited personnel resources and lack of skills reduce the ability to use innovative technologies and to participate in research and development activities. Finally small and medium sized shipyards often lack the access to information and cooperation networks, which are available to the large shipyards. For these reasons, SMARTYards aimed at improving the productivity of the production processes of small and medium sized European shipyards and related subcontractors working with them.

To achieve this objective SMARTYards has:

- Developed, tested and validated six prototypes selected from a pool of 25 technical ideas proposed in 7 different technology areas.
- Investigated the productivity of each prototype, its impact on Environment, Health and Safety and its opportunities for the shipyards production processes.
- Prepared and tested training material for the prototypes.
- Developed a concept for a sustainable Research Development and Innovation Network for SME Shipyards involving European Maritime Cluster Organisations and the SMARTYards Consortium.



### 4.1.3 Main S&T results/foregrounds

The shipyard's production process includes all processes from design through engineering (production preparation) to manufacturing, assembly and outfitting. Even though design processes are not part of the core field of work of small and medium sized shipyards, these have been included in the project as they are mostly carried out by SME companies and due to their importance for the whole building process. Maintenance, repair and retrofitting processes are incorporated, being an important business area for smaller shipyards.

SMARTYards identified seven Technology Areas (TA) that characterize the design, production and delivery processes of a shipyard. For each area design studies were made to identify technological ideas for improvements for shipyards' business processes and their savings potential. The results were documented in the SMARTYards Solution Catalogue.

A comprehensive Technology Catalogue for the seven Technology Areas was developed. This SMARTYards Solution Catalogue proposes smart solutions (equipment, design for production and process organization) to improve productivity in small and medium shipyards. Additionally, in order to sustain this catalogue's usage after the end of the SMARTYards project, a methodology to collect, assess, select, adapt and validate optimized and holistic solutions for small and medium sized yards was prepared. In conjunction, a WIKI platform was set up as a possible tool, being an online platform wherein the elaborations of design studies can be maintained online by the users.

Six Prototypes were successfully developed and validated in the SMARTYards project. They are,

- Methods to improve the Efficiency of Distributed Design Processes
- Advanced Planning in Shipyards using Simulation
- Work Content and Weight Estimation Tool in Early Planning
- Simple, mobile and flexible welding equipment
- Portable Container Workshop
- Innovative Materials Catalogue and Joints Catalogue for dissimilar materials

#### 4.1.3.1 Prototypes

##### **Work Content and Weight Estimation Tool in Early Planning**

###### *Problem*

The work content estimator is intended for use at shipyards not having their own design office and where the initial work content -, weight - and cost price indication for a new ship is based on the input of many persons, each contributing from their own expertise.

###### *Achieved results*

The Work Content Estimator (WCE) is designed to extract geometric properties from a ship's general arrangement plan drawn in AutoCAD into structured data in Microsoft EXCEL. This enables the shipyard to speed up the process of initial cost price estimation in the pre-contract phase. It further provides the shipyard with an initial weight and work content estimation. Due to a user friendly Graphical User Interface, the process of data extraction can easily be controlled.



### Benefits for SME shipyards

- Significant reduction in work activity for calculations
- Reduces errors and increases the reproducibility and quality of documentation
- User friendly as it prevents the need for complicated and integrated software tools
- Compatible with AutoCAD which is much used in the shipbuilding industry
- Secures knowledge that is now in the heads of shipyard's employees



### Methods to improve the Efficiency of Distributed Design Processes

#### Problem

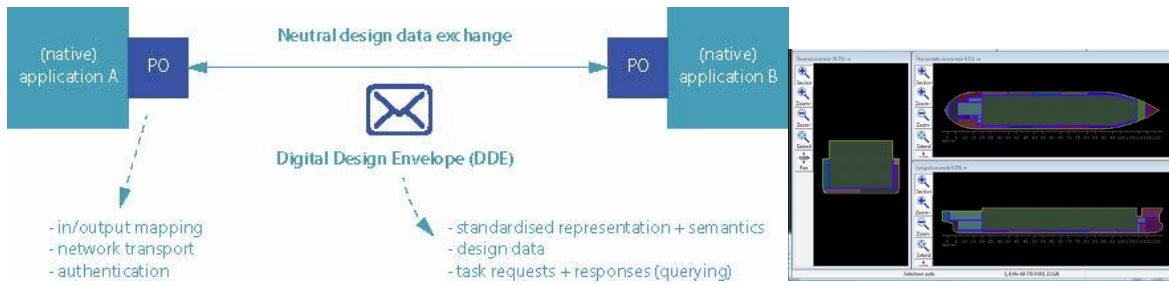
During the ship design process many specialists work together, each addressing a certain aspect of the ship's design such as stability or construction. For this they use specialised 3D software tools. The challenge is to maintain consistency of data between these tools during the design process and the production (preparation) process at the shipyard.

#### Achieved results

This SMARTYards prototype is designed for design data exchange between a 3D hull arrangement software package and a 3D ship stability software package. It is based on a “two way data exchange portal” ensuring consistency of data between these two packages. The communication is via internet without using central data storage. The applications use each other's methods without having direct access to each other's data structures and storage. The prototype can be used within the shipyard or as enabler for a distributed design process between the shipyard and strategic partners, like for instance a design office.

### Benefits for SME shipyards

- Large time savings during the design process
- Reduces the probability of errors
- Improves consistency of data
- Supports tasks performed on different locations
- Easier collaboration between SME shipyards and design offices



### Advanced Planning in Shipyards using Simulation

#### *Problem*

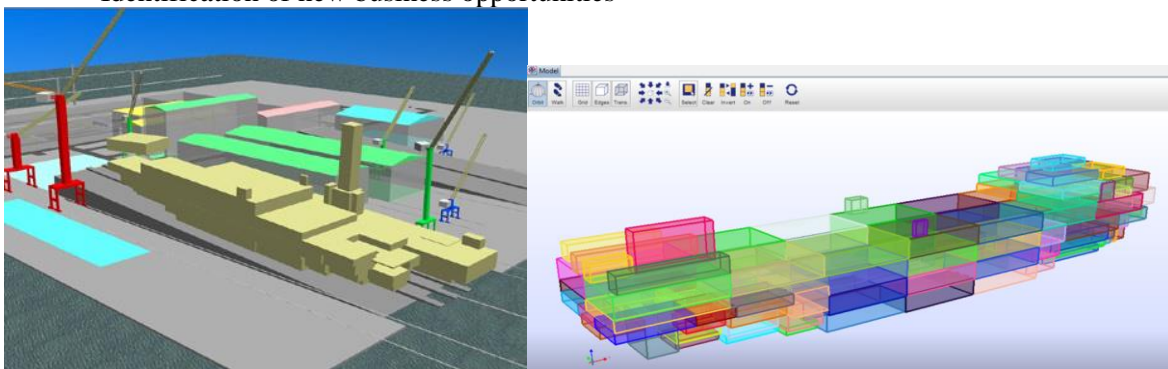
In order to be competitive, shipyards must optimise the use of available resources and decide on strategic partnerships. To achieve this, many different aspects must be taken into account, since the design, construction, outfitting and delivery of a new ship is a complex process. Simulation is one solution to tackle these challenges.

#### *Achieved results*

This SMARTYards prototype is designed to simulate the shipyard's production processes. It enables the shipyard to identify scenarios to optimize the use of available resources. It further gives insight in the options to take up and manage a larger number of projects simultaneously. The core elements are the Shipyard Planning and Support Interface (SPSI) and the Shipyard Simulation Model. The SPSI is the shipyard's planner interface which is used to handle data required for simulation. The simulation database is specifically developed for the needs of the shipyard where the simulation will be used.

#### *Benefits for SME shipyards*

- Optimization of the use of available resources
- Insight in consequences of various assembly sequences
- Structured gathering of historical data, thus improving the quality of future simulations
- Identification of new business opportunities



### Simple, mobile and flexible welding equipment

#### *Problem*



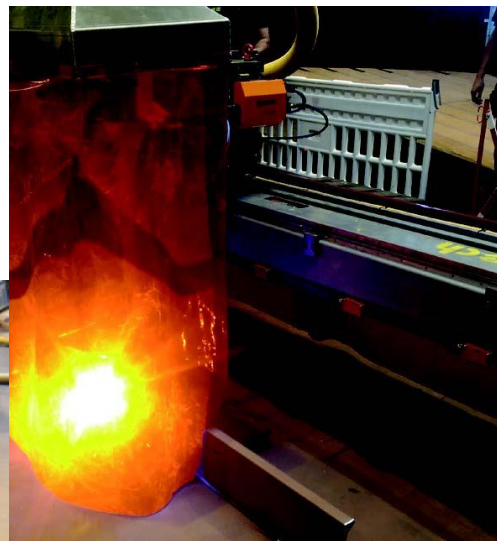
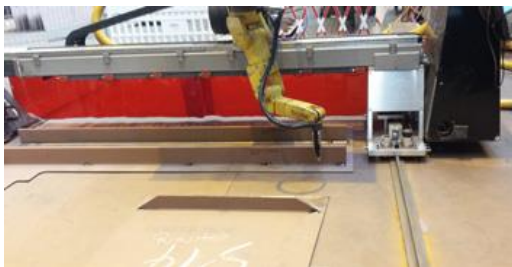
Where larger shipyards have automated their welding processes, SME shipyards often lack the financial resources for the purchase of this type of equipment and the knowledge to programme them. As a result welding work is done manually.

*Achieved results*

The SMARTYards Welding Robot is designed for the automation of the welding process for unified large flat panels (welding stiffeners on a flat plate with certain frame distances, or similar) and micro panels with more complex welding routes. It consists of a gantry on which the welding robot is positioned and a scanning system that provides the robot with the needed information. The system comes with pre-programmed welding scenarios, allowing the operator to select the required scenario after which the welding robot proceeds with its task autonomously. The welding robot is designed to be implemented in a micro panel line.

*Benefits for SME shipyards*

- Reduction of the amount of manual welding activities
- Automation of repetitive manual welding
- Runs on a simple gantry
- Can be operated during night shifts and/or parallel with manual welding tasks
- Robot can be shared between shipyards



**Portable Container Workshop**

*Problem*

Due to space limitations, lack of financial means or other factors shipyards not always have the possibility to optimise the layout of the shipyard in relation to the production process. This often results in a loss of productivity due to the fact that workers need to go to the main workshops for small tasks.

*Achieved results*

This SMARTYards prototype is designed to provide shipyard workers with a workshop containing preselected tools, machines, and materials at their work location. By providing this workshop shipyard workers can perform tasks without going to the main workshop, thus increasing their productivity. The workshop is a contain-



er and positioned on a floating pontoon. This pontoon is moved around the shipyard bay and moored alongside the ship where the work needs to be done or in close vicinity alongside a quay.

*Benefits for SME shipyards*

- Increases productivity of workers
- Small tasks are performed at the working location
- Prevents disruption of serial activities in the workshops
- Can be used alongside ships or hoisted on their deck
- Pontoon can be used for transfer of goods



**Innovative Materials Catalogue and Joints Catalogue for dissimilar materials**

*Problem*

As long as class rules remain the main problem to introduce new materials (mainly non-metallic materials and the specific joining between them), many SME shipyards avoid to demonstrate potential customers that these materials have many advantages compared to the use of traditional steel. As a result they have fallen behind in development, knowledge, skills and experience.

*Achieved results*

This SMARTYards prototype is designed to provide a shipyard with knowledge about the use of composites in shipbuilding and ship repair by means of a physical demonstrator and a best practice composite handbook for shipyards. The purpose of the demonstrator is to establish knowledge in shipyards working at present with steel only. By testing and demonstrating different structural forms and joining techniques for combinations of materials, the implementation of composite components in shipbuilding is shown. It is considered that the Composite Service Deck is the best solution to enable a shipyard to see, understand and explain the benefits of composite materials to its employees, customers and relevant third parties like class societies.





The best practice composite handbook for shipyards is the other element of this prototype giving a short overview for non-experts into composite for maritime application.

*Benefits for SME shipyards*

- Enables shipyards to decide where composite applications are feasible under the current rules and regulations
- Provides knowledge to assess the impact of the use of composites on productivity, resources, activities etc.





#### 4.1.4 Expected impact

The main objective of the SMARTYards project is to test and validate SMART technologies that can be adapted to a Small and Medium Sized Shipyard and thereby increase their productivity by around 20%. During the design, testing and validation of the six SMART technology prototypes in the project, it was identified that the quantifications of the improvement in the productivity was not very straight forward. This was due to the diverse nature of the 6 different SMART technology with regards to their area of implementation and their corresponding effect on the SMEs working style. Therefore, four Main performance indicator categories were selected to measure the impact of the SMART technologies in the Shipyard. Then Main performance indicators were

- Cost (influenced by the total cash flow in a year)
- Time (influenced by the change in the lead time of a process)
- Quality (influenced by the change in the quality of product or process)
- Return on Investment and Payback (influenced by the cash flow and payback period for the SMART technology investment)

Apart from the aforementioned four performance indicators, in each SMART Prototype impact assessment, scenarios were defined that reflect the various methodologies in implementing the SMART technology in a Small and Medium Sized Shipyard. Apart from assessing the impact of the six SMART technology prototypes individually, an assessment was carried out to analyse the impact of implementing all the six SMART technology prototypes in each of the Shipyard involved in the Project.

The implemented SMARTYards technologies proved to introduce significant changes into the processes in the shipbuilding industry. Every technology impacts the processes in a different way. Technologies like the welding robot and the container workshop have a direct and straightforward impact on the processes, while other technologies like the simulation and composite materials have an impact on many processes and can change the way how processes are performed altogether.

It was shown that the reduction of the process times through the technologies ranges from -0.2% to 78.1% (average: 32.8%). If similar technologies were to be implemented for every process in the shipbuilding industry, huge improvements could be achieved.

To assume the impact of the technologies on specific shipbuilding projects, three additional productivity assessments have been performed. It has been shown that for the participating shipyards a mean reduction of personnel costs of about 20 % can be achieved by applying the SMARTYards technologies on exemplary shipbuilding projects.

The financial assessment showed that the payback time of the technologies ranges from 0.46 to 2.74 years (average: 1.6 years) and the ROI ranges from 65.0% to 874.1% (average: 328.9%) for 5 years (considering 5% interest rate). Thus, the technologies do not only reduce the input significantly but are also very good for the cash flow at the companies. In the brief summary of the impact assessment of the six SMART technology prototypes in the following sections, the performance indicator “Cost” has been combined with “Return on In-



vestment and Payback”, as the ROI and Payback estimation involves the consideration of the yearly cash flow in the organisation due to the introduction of the SMART technology.

**Methods to improve the Efficiency of Distributed Design Processes**

Scenarios:

The Prototype “Methods to Improve the Efficiency of Distributed Design Processes” has a direct impact on the time spent by the design offices in handling the information changes that are under continuous improvement during the early phases of the design either in the 3D Steel Hull Arrangement Tool or the Stability Tool. Since the increase of labour productivity is the main effect of this technology, the evaluation focused on the measurement and estimation of working times in the affected process. The impact of the SMART technology strongly depend on whether only the preliminary design is evaluated or the complete design process. Therefore, the scenarios under which the impact assessment of the prototype analysed were:

- Preliminary design
- Basic Design 1<sup>st</sup> phase
- Basic Design 2<sup>nd</sup> phase

In the Preliminary Design phase, the Smart Technology allows a faster start-up of the project set-up, of the Steel Plan and/or the stability model. During Basic Design phases, once the initial stability model, 3D General Arrangement and 2D drawings have been set up, they are further elaborated. In this phase, there is a lot of two-way data exchange between the design tools. Every time data is transferred, time is saved. Secondly, a lot of manual / traditional data exchange would normally significantly raise the chance of errors. With the Smart Technology, this chance is significantly reduced, also reducing the time necessary for thoroughly checking the design models for inconsistencies.

For the Return on Investment (ROI) analysis, further more scenarios were defined. This was necessary to have a transparent outlook on the possible other software available with design offices or shipyard and the phase in which they would utilise the SMART technology. There are two common cases, to which extent the design is elaborated with the technology:

- Only the preliminary design is elaborated or
- The preliminary and the basic design are elaborated.

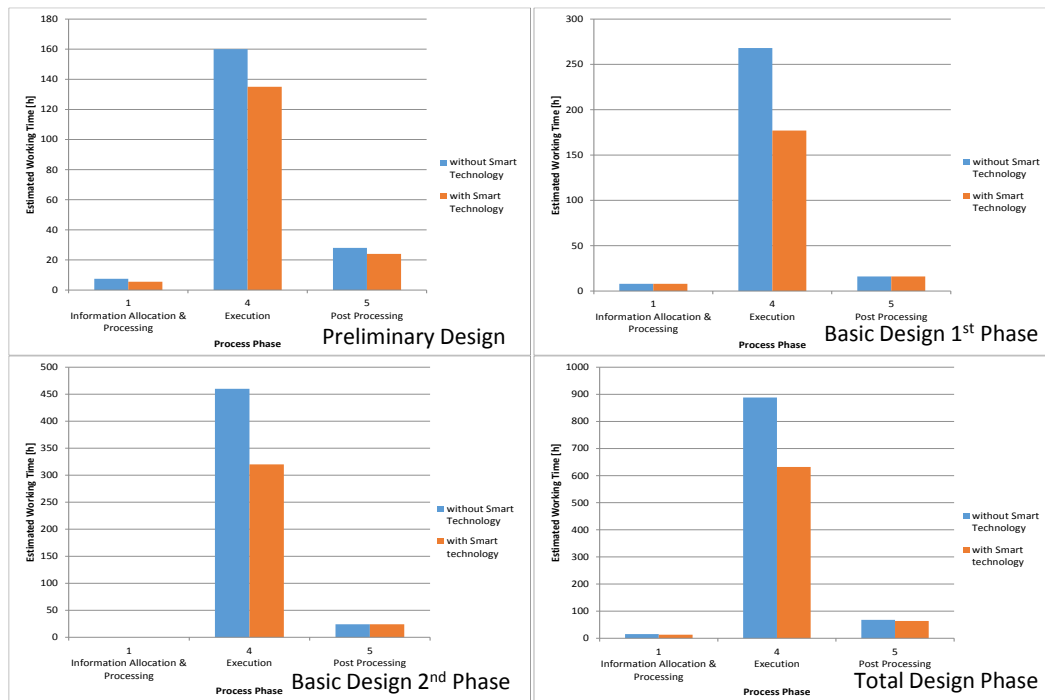
Furthermore, the shipyard applying the technology either already uses the required ‘basic software’ or it uses other software and has to purchase this software. This results in four different scenarios for the Return on Investment calculation.

Possible scenarios for End-User for ROI calculation			
		To what extent is a design elaborated with the technology?	
		Only Preliminary Design is elaborated with the technology	Preliminary Design as well as Basic Design are elaborated with the technology
Basic software already in use?	Yes, basic software is already in use by the End-User and user has basic knowledge of this software. Only purchase and training of SMARTYards prototype software is necessary	Scenario 1a	Scenario 1b
	No, basic software is not already in use at End-User. So basic software has to be purchased as well and training has to be arranged	Scenario 2a	Scenario 2b



Impact in Time:

The SMART technology was analysed to help the design offices to save time in the areas of “Information Allocation & Processing”, “Execution” and “Post Processing” stages of the design phases. It was visualised that around 27% of time is saved in the design phase, if the SMART technology was implemented. The distribution of the time saved varies between 13% in “Information Allocation & Processing”, 28% in “Execution” and 6% in “Post Processing” depending on the methodology of implementation.



Impact in Quality:

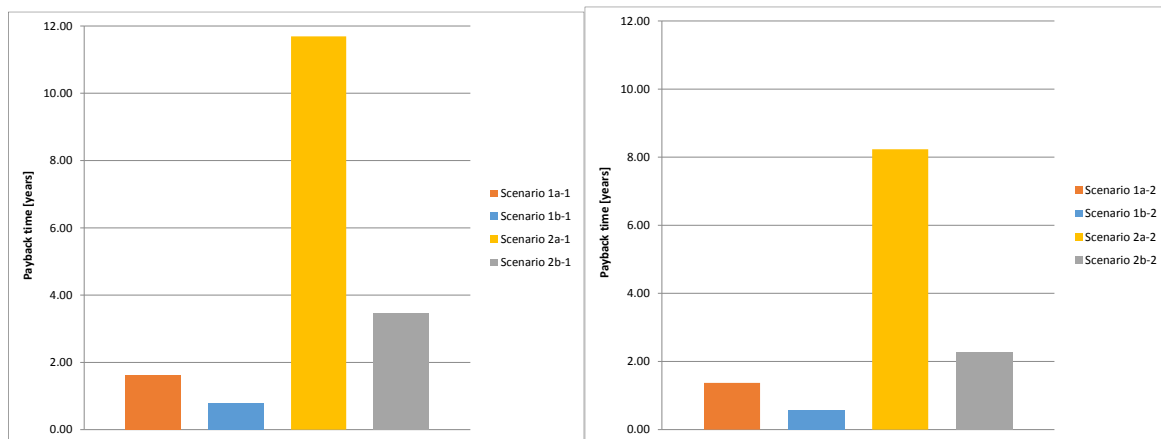
The SMART Technology improves the consistency of the design data used in the project significantly, by reducing the amount of errors or chance of errors in the presented data. It also results in less communication errors between parties. The improved cooperation between parties indirectly improves customer satisfaction, too. Additionally, the saved time in the design process could be utilized to optimize the design according to the customers’ wishes. Because a two-way exchange of design data is performed quicker and more reliable, communication between designer, engineers, and subcontractors is improved or even made possible for the first time. This results in less communication errors and (relational) problems between parties. Time saved in the rework can be used to investigate design alternatives and improving the design parameters, resulting in a more optimized ship.

Customer satisfaction is a very broad term. For this technology however, it is related to the price asked for a design and/or engineering package, the needed lead time/throughput time, the overall quality of the design and the quality of the delivered documents. Assuming the reduction in man-hours for a design project, the price asked for a design package can be reduced, directly improving customer satisfaction. Since the lead time is affected as well by the technology, the customer will get a result much quicker which increases customer satisfaction as well.



Return on Investment:

The cost factors taken into consideration during the ROI calculation are the licence cost for the software, running cost for the software and the personnel cost of the designers utilising the SMART technology. The investment cost and the running cost differs between the Scenario 1 and Scenario 2 defined for the ROI. This is due to the assumption of some already available design software with the shipyard, thereby reduced investment and running costs in case of Scenario 1. The personnel cost savings between the scenarios depend on whether the SMART technology is used either in one or both of the Preliminary design phase and Basic Design phase. The Payback period of the SMART technology varies from 1 year to 10 years, if it was assumed that the time saved from the SMART technology was not used for new projects, as the market situation might not be good (Right pic below) . The Payback period of the SMART technology varies from less than 1 year to 8 years, if it was assumed that the time saved from the SMART technology is used for additional income via new projects available in the market.



**Advanced Planning in Shipyards using Simulation**

Scenarios:

The Prototype “Advanced Planning in Shipyards using Simulation” is developed with three software packages. They are Plant Simulation, Simulation Toolkit Shipbuilding (STS) and anteSIM. With Plant Simulation and STS already available in the market, in order to compare the benefit of introduction of the anteSIM software and the concept in the SMART technology, four scenarios were used in the Productivity Analysis. In each scenario, one or combination of the abovementioned software are used in tandem.

Scenario	software tools for simulation and support		
	Plant Simulation	STS Toolset	AnteSIM
1 – Conventional Planning	No	No	No
2 – Planning with Simulation	Yes	No	No
3 – Planning with Simulation	Yes	Yes	No
4 – Planning with Simulation	Yes	Yes	Yes



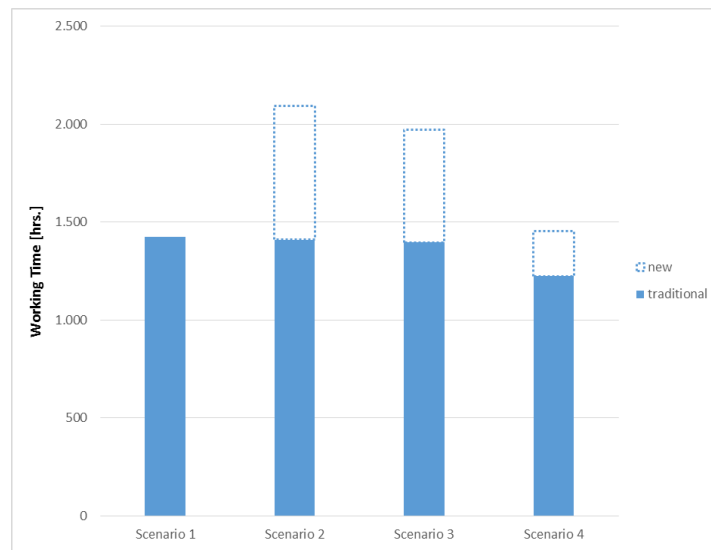
To investigate the impact of the SMART Technology, an assembly of ship blocks on slipway is used as a case study. The relevant identified planning activities were performed using the technology (Scenario 4). The activities of the average planning process in an SME shipyard or design office without using the technology (Scenario 1) were extracted from old projects where possible and estimated where it was not possible. The times for Scenario 2 and 3 were estimated based on the experience of the technology developer.

For the Return on Investment (ROI) estimation, since all the aforementioned software packages can be utilized by the Shipyard in the SMART technology either with Run-Time licence or Developers licence, the initial and running costs for both the cases were analysed. Since, the impact of the improved production planning process is not only in the production planning department but also in the execution of the production processes in the facilities at the shipyard, the impact of the improved production plans were assumed under four sub-scenarios (optimistic, Status Quo – 1, Status Quo – 2 and pessimistic).

*Impact in Time:*

The introduction of the SMART technology in the shipyard planning has impact on the lead time of the planning department in finalising a production plan and also on the lead time of the production facilities to complete the building of a ship/ execution of their production processes. In the analysis of the impact of time, the impact of the SMART technology only in the planning phase has been analysed. The impact of the improved plan in the lead time of production process have been taken into consideration during the ROI calculation, as it has an indirect impact. In the analysis on the impact of SMART technology in the planning phase, the planning activities that are affected were categorised into Pre-Contract and Post-Contract phase. It was visualised in the analysis that the SMART technology not only decreases the personnel effort in certain traditional activities but also increases in new activities due to the SMART technology and traditional activities. But, as a whole, it was found (see pic) that due to the implementation of the SMART technology in the shipyard planning, even with reduction of 14% personnel effort in traditional activities there is around 16% additional personnel effort required due to the new activities introduced by the SMART technology.

It is to be noted, that the impact of the improved plan in production facilities is not taken into consideration in this analysis. The shipyards in the project also stated that if there is an improvement in the execution of production in the facilities, they would very much support a small increased effort in the planning phase. This is due to the reason that the plans have more significant in the costs in the production execution than planning. Additionally, as the shipyard becomes more accustomed to the functioning of the SMART technology, the aforementioned additional personnel effort might be reduced due to less training and faster collection of data for planning analysis.

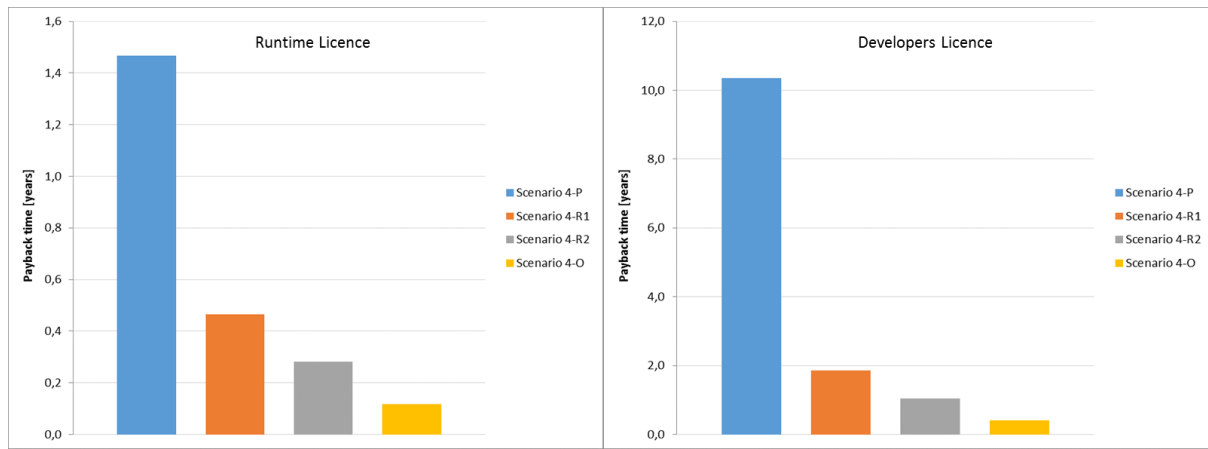


Impact in Quality:

The production schedule is an important factor for the successful building of ships. A bad production schedule needs to be revised more often during the production than a good one. The technology helps in finding a superior schedule that reduces rework in the planning department. Additionally, it also indirectly increases the quality rate in the production. Changes in the schedule without proper preparation can lead to errors, that otherwise wouldn't have occurred. This Technology increases customer satisfaction as one of important goals of SMEs. This is mostly the result of keeping deadlines and thus a higher level of confidence. Additionally, the Technology can be used to raise level of Customer's satisfaction by visualizing the production plan in the beginning of the project and during the production.

Return on Investment:

The impact of the SMART technology on the economic operations in the shipyard are in the savings in the Planning department as well as the Productivity facilities which are analysed and implemented with improved production plans. The cost savings were considered in the areas of improved personnel and machinery utilisation, improved lead time resulting in reduced docking cost and penalties and reduced inventory costs. The investment costs considered in the ROI calculation for the SMART technology are the licence cost and maintenance cost of the software (developers and run-time licence) and additional personnel costs involved in training and execution. The SMART technology is capable of aiding the SME shipyards to generate better plans just with the use of run-time licence. With the developers licence, the estimated ROI is calculated to be between around 1,5 years to 0,5 years (see pic). Even with the increased investment under developers licence, the ROI estimations is only around 10 years under pessimistic assumptions but under Status Quo and optimistic assumptions it is within 0,5 to 2 years.



### Work Content and Weight Estimation Tool in Early Planning

#### Scenarios:

The Prototype “Work Content and Weight Estimation Tool in Early Planning” aids the shipyards in calculating the areas and volumes to determine the necessary insulation covering, bath and kitchen areas (for interior design calculations of tiles and other materials), floor, wall and ceiling covering for the vessel (wood or other materials). With the SMART technology it is possible even for SME shipyards with no design offices to perform the initial calculation of the work content and weight estimation during the early phases of the contract negotiation where only a draft version of the GA is available. Therefore, in order to visualise the impact of SMART technology in different kinds of shipyards, the assessment was performed with background data from a SME Shipyard with no design office and a bigger shipyard with their own design office.

#### Impact in Time:

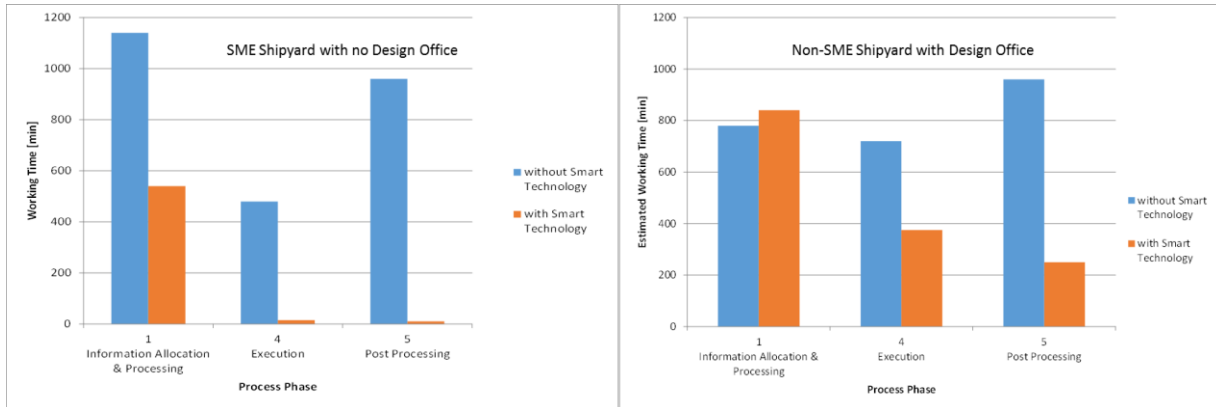
Early cost estimations can be very time consuming for SME shipyards. The SMART technology automates a significant effort involved in the early phase processes. The activities performed during the work content and weight estimation in the early phases have been categorized into the three main steps – Information allocation & processing, Execution and Post Processing. Out of the mentioned three main steps the SMART technology automates all the activities categorized under Execution and Post Processing. The activities under the Information allocation & processing step is partially automated. Additionally to the impact in the design department, the technology could potentially increase fitness for production of the design. This could be achieved by reducing errors and increasing consistency of the design data. The end-user estimated that an additional improvement in productivity can be achieved of 1-2% in the production processes and thus in lead-time of the total project.

With the possibility of automatizing the activities of the work content and weight estimation at early phase, the personnel effort required to complete the initial draft of the contract to the customer has been drastically reduced. The impact is more pronounced in SME shipyards, with reduced personnel effort in the range of 52% in Information allocation and processing step, 96% in Execution step and 99% in post processing step. This is mainly due to the reason that the SME shipyard with no design offices now has the possibility to perform these activity with just a click of a button in the SMART technology tool. Even in a non-SME shipyard who





have their own design offices there is an increase in effort of around 7% in Information allocation and processing step but a significant reduction of about 47% in Execution step and 74% in the Post processing step.



Impact in Quality:

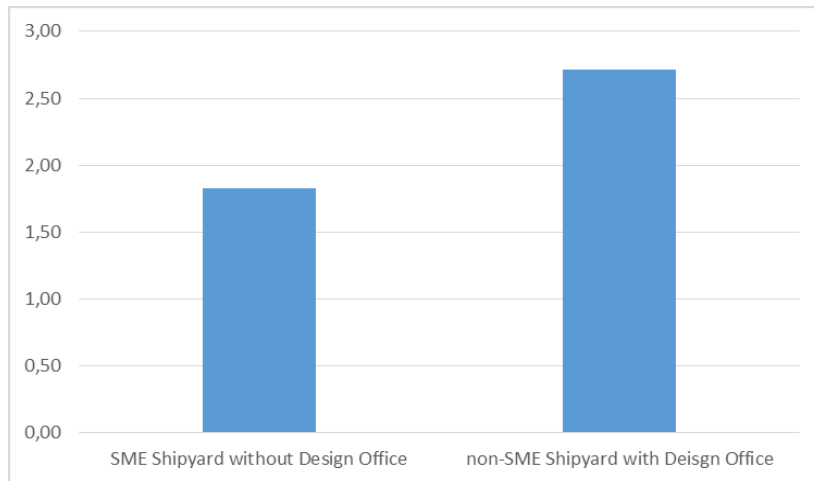
This prototype allows improving the quality rate in the early design phase as it automates some processes, which normally are subject to human error. In addition, the increased speed of the process might free up some time for the engineers, thus allowing them to check the results.

The prototype also has an indirect impact on the production. Through more precise work planning and the design stadium, a higher quality can be gained and less rework is necessary. Effects on quality are given through a systematic analysis of the production chain and thus a very detailed optimization. Those optimizations can affect the process-steps mentioning duration of the single stations and optimization of process-functions as well

Quality improvement is achieved indirectly as respect to the customer, following as a result of the prototype use in early stages of the cost estimation activities since it accelerates the calculations: what was currently done by hand now is done IT-based with the help of the prototype – with less errors, reproducible way, quickly, and well-documented. Giving a fast and documented response to the customer requirements is initiating an initial bridge in the following discussions regarding a potential new contract.

Return on Investment:

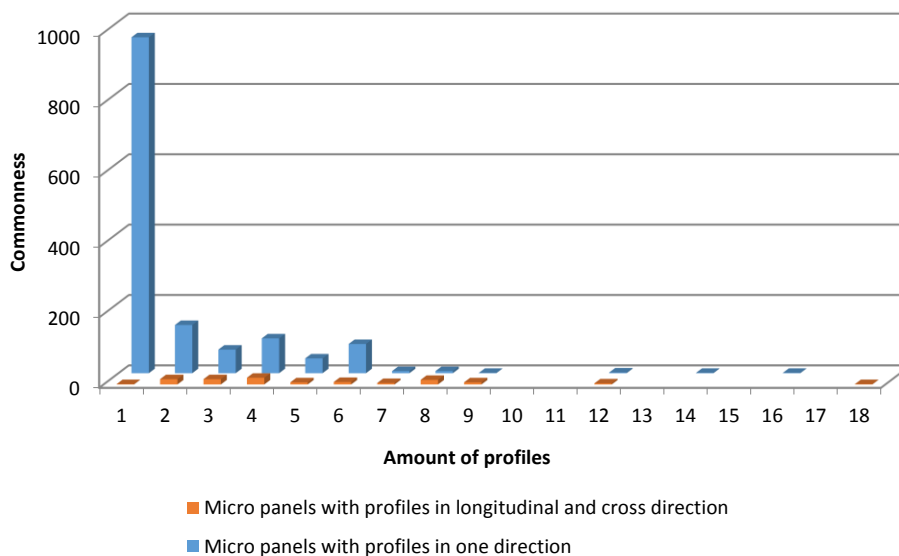
In the ROI calculation for the SMART technology, the initial costs taken into consideration are the licence cost for a CAD software (AUTOCAD) and Excel. Along with it the personnel cost of the shipyard personnel are also included in the running costs for the SMART technology. The savings from the SMART technology is only from the Personnel cost saved from the significant reduction in the effort required, as mentioned above. With these cost factors into consideration, it was estimated that for a SME Shipyard without a design office the ROI is around 1,7 years and for a non-SME shipyard with design office the ROI to be around 2,7 years.



**Simple, mobile and flexible welding equipment**

*Scenarios:*

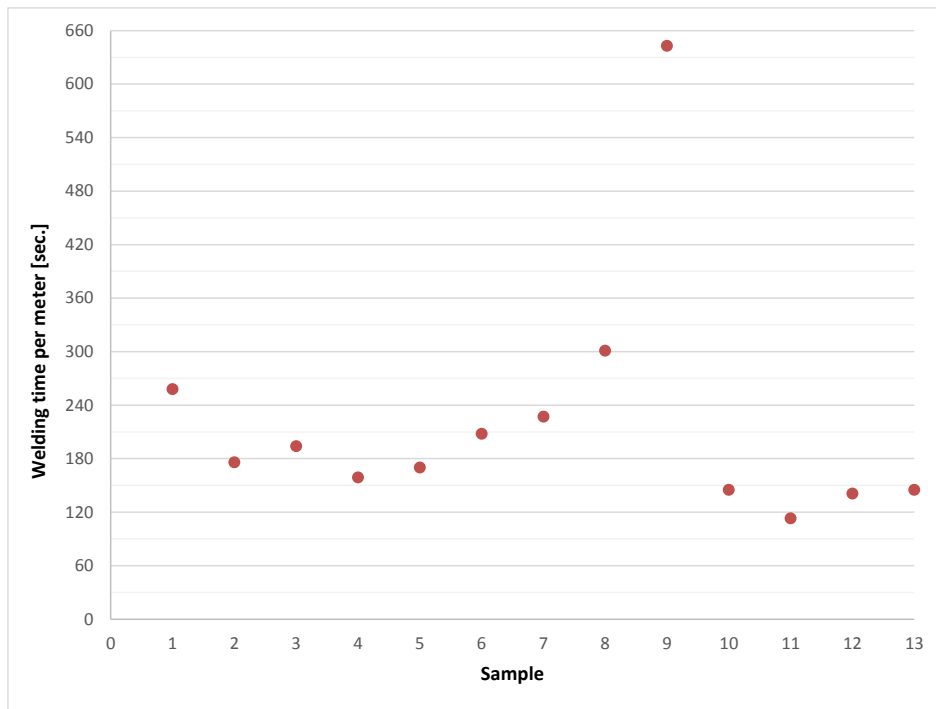
In the prototype “Simple, mobile and flexible welding equipment”, a welding robot in the micro panel production was tested and validated. In the shipyards involved in the project, it was identified that the welding of micro panels is mostly done either by hand or with welding tractors. These micro panels show a high variety in dimension and complexity. In the scenario for the assessment in the Project, an analysis of the types of micro panels usually used in a RoRo ferry was carried out to determine the applicability of the robot. It showed that a high number of simple micro panels is produced, which is ideal for an automated welding robot process. Around 70 % of micro panels that are built mainly consist of one base plate with either profiles in one direction or profiles in longitudinal and cross direction. The biggest share of these micro panels only has one profile on one base plate as it is shown in figure. A certain amount of these are T-beams that are not weldable by the T-beam-line. In the evaluation, the welding times of the existing welding tractors has be compared with the times of the welding robot to determine the impact on productivity.



*Impact in Time:*



In order to assess the SMART technology, the welding time of defined Micro panel were measure when weld-ed using welding tractors. The figure below, shows the measured welding time per meter for Micro Panel used in the validation process. The welding speed of the welding tractor is calculated as an average from the meas-ured samples. The outlier in the below chart was not used in the calculation of the welding speed, due to the maintenance issue that occurred during the testing of that particular sample.



A detailed testing of further three Micro Panels were performed using the SMART welding robot. The total welding time for the SMART welding robot to complete the three Micro Panels were then compared with the estimated welding time of the welding tractor with the equivalent welding length. The comparison showed that the welding process with the robot is 39% slower than the welding process with the welding tractors and the manual support. However, it is to be noted that SMART welding robot does not require any supervision and there are no manual welding tasks pending while using the SMART welding robot. This translated to a conclusion that even though the welding process as such has increased in time, but the personnel required to perform the equivalent tasks is around 1-2 personnel less with the SMART welding robot.

Impact in Quality:

The impact of the technology on the quality of the welding seams depends on the amount of rework before the introduction of the prototype. For example, if the robot is replacing welding tractors, the quality is expected to be similar. However, there is a chance of quality improvement if there is angular misalignment of the profile. The robots sensor considers the impact a lot better compared to the tractor. In the unlikely case of large angular misalignment, the tractor cannot weld properly on the two sides of the profile.

In the end-users case, there was only minor rework on micro-panels without the technology. Thus, the impact of the robot will not be significant. Tests of the welding quality showed, that the robot leads to sufficient welding quality in the end-user case. There is potential for optimizing the process with respect to reducing the



design throat thickness and thus, the heat input in the future. This might have impact on the distortion of the micro-panel and thereby on the effort for straightening work

Return on Investment:

In the ROI calculation, the investment and running cost of the SMART welding robot and the Personnel cost involved with the operation of the welding robot were used. As explained before, the welding robot reduces the required personnel at the Micro Panel line and it was estimated that the total personnel working time saved due to reduced personnel would be around 14%. This resulted in an estimated ROI for the SMART welding robot to be around 2,15 years. This estimation may vary depending on the wage structure of the shipyard in consideration.

**Portable Container Workshop**

Scenarios:

The Prototype “Portable Container Workshop” aids in reducing the transportation and material logistic time between the Shipyards Slipway/Dock and the Shipyard workshop, during the execution of various small to big manufacturing jobs involved in a typical Ship Repair order. For the assessment on the time saved from the SMART Container Workshop on implementation in a shipyard, three scenarios were taken into consideration. They are, reference case of shipyard with no SMART container workshop, shipyard with a SMART Container Workshop but without space to store material required to be used on board for immediate repair jobs and shipyard with a SMART Container Workshop and space in the Container workshop to store material for upcoming immediate repair jobs. While estimating the ROI calculations for the SMART Container Workshop, four scenarios were considered. Each scenario varied with the inclusion of Pontoon along with the container and the material used in building the container.

Scenario	Main material	
	Aluminum	Steel
with Pontoon	1	3
without Pontoon	2	4

Impact in Time:

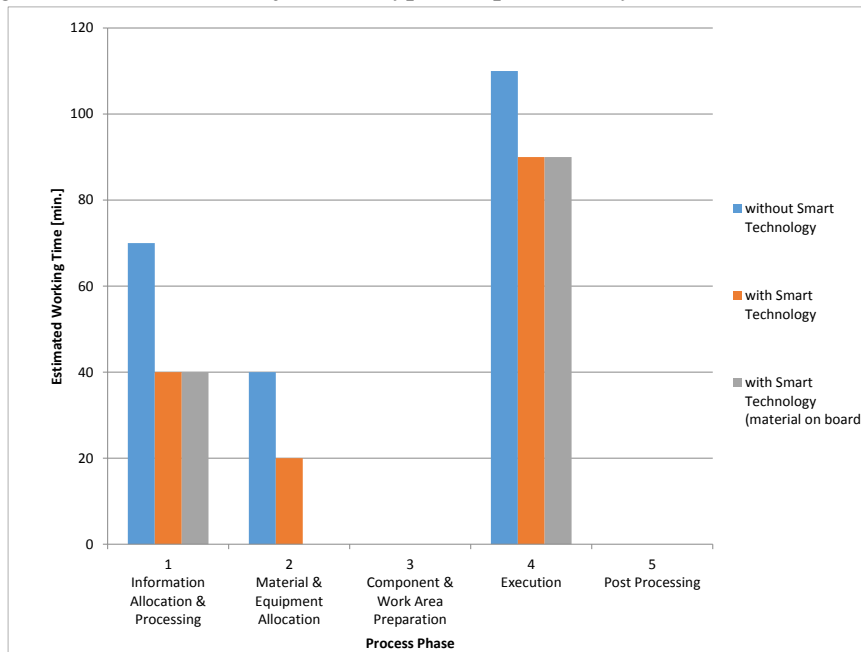
During a shipbuilding and repair, many activities require small machining operations, which force workers to move from the ship to centralized workshops. Additionally to the possibility of having to wait for a free work space in a centralized workshop, the activities can also disturb the normal workflow in that workshop. In the Project, for assessment the activities that were taken into consideration as typical set of activities during one such repair job (pipe segment) was,

- identify the piping segment to be replaced (on board of the ship)
- determine necessary materials and operations
- cut / disassemble old pipe segment and take measures for the new piece
- travel to the workshop
- get materials, wait for free work space, cut a raw shape of the new material (or wait for completion)
- travel back to the ship
- check the pipe dimensions and it’s components and adjust if necessary



- travel to the workshop
- finalize the welds
- travel to the ship
- mount the new segment

The abovementioned activities were grouped into categories shown in the chart below. It was estimated that due to the introduction of SMART Container Workshop, there can be around 42% reduction in time at Allocation & Processing phase, 75% reduction in time at Material and Equipment allocation phase and 18% in the Execution phase. As seen in the chart, if the SMART Container workshop has provisional space to store material for upcoming repair jobs, there is a possibility to reduce the time at Material & Equipment allocation phase to up to 99% (depending on the space available for storage in the Container Workshop). It was estimated during a one month validation of the SMART container at the Shipyard, that there can be around 36% reduction in working time for execution of jobs of a typical repair activity.



Impact in Quality:

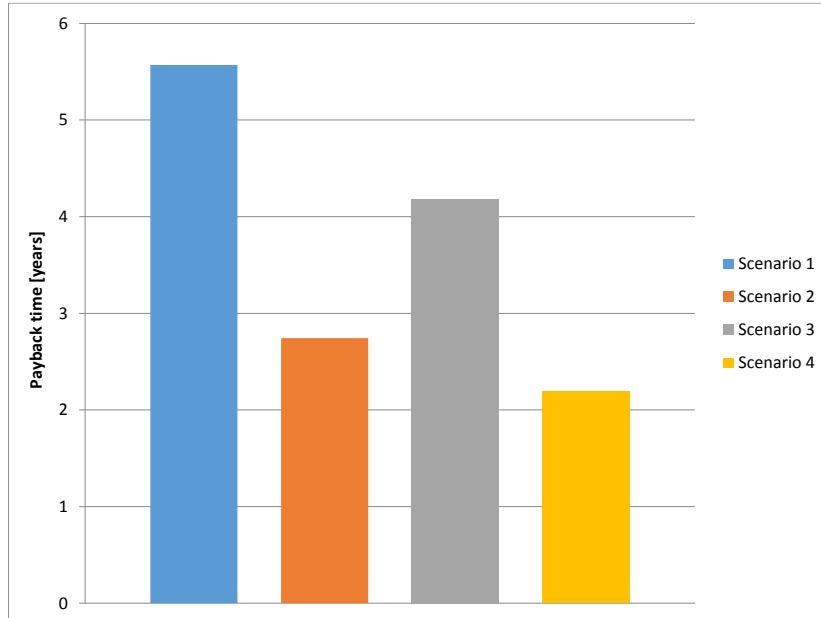
The quality of the activities performed in the shipyard is not affected on whether the activities is executed in a SMART Container workshop or Central Workshop. Therefore, the SMART Container Workshop does not have any impact in quality of the individual production activities. The reduction of lead-time has a small impact on the delivery time and thus the customer satisfaction.

Return on Investment:

In the ROI calculation, the investment and running cost of the SMART Container Workshop and the Personnel cost of the shipyard personnel involved in the activities inside the SMART Container Workshop have been taken into consideration. The Investment cost of the SMART Container Workshop varies in the aforementioned four scenarios for the ROI calculation based on the existences of a Pontoon along with the SMART Container Workshop and on the material used (Aluminium or Steel) in building the Pontoon and SMART



Container Workshop. It was estimated that the ROI ranges from 2,1 years to 5,6 years, depending on the scenario under consideration.



### **Innovative Materials Catalogue and Joints Catalogue for dissimilar materials**

#### **Scenarios:**

The Prototype “Innovative Material Catalogue and Joints Catalogue for dissimilar materials” is a complex topic with several possible applications. During the course of the SMARTYards project, it was not possible to investigate the feasibility all the possible applications. To get to know the new processes that are connected with the technology and to demonstrate the benefits of it, a physical prototype – composite service deck, consisting of composite material was designed and built. During the production of the composite service deck, the time required in the various phases of the design, planning and production phases were measured, so as to be compared with the time required of an equivalent service deck built with steel. For the ROI investigation on introducing a composite production capability in a shipyard, two scenarios such as, a shipyard capable of adapting to the new production processes with their already existing production facilities (Scenario 1) and a shipyard who have to start from scratch to set up a composite production facility (Scenario 2) were assumed. Additionally, three scenarios were defined to represent the different percentages of the ship components being replaced with composite materials (2%, 5% or 10%)

#### **Impact in Time:**

The introduction of SMART composite structure in the ship has an impact on the processes in the following general stages of shipbuilding:

1. Pre-design phase

In this phase, the shipyard has an initial idea of the ship from the customer requirements. The level of detail is variable. Therefore, the impact is only on the time required by the management to make a



strategic decision on whether to determine the particular parts of the ship that will be built of composite materials.

2. Detailed Design phase

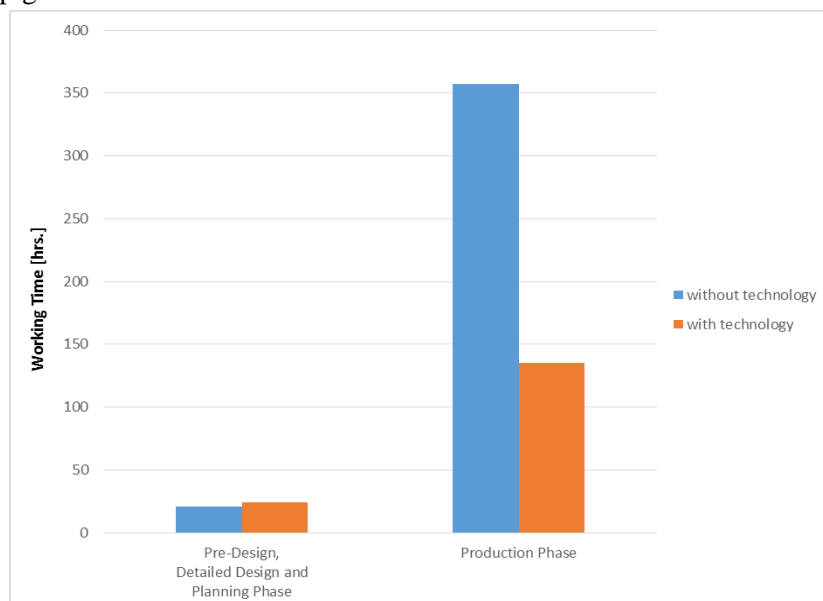
Once the initial design is decided, the detailed design of the parts has to be performed. Extra time for this technology is spent on deciding about joining, manufacturing, outfitting and fixing methods. However, for the basic stability calculations that are done in this phase, the necessary time reduces, as the weight of the composite parts is lower. This positive effect of the technology does not only occur in new buildings but also when composite components are added to an already existing ship.

3. Planning phase

Planning the production of composite components is easier in comparison with steel components. This is mostly due to the fact that the processes that produce a lot of heat are eliminated. The impact depends on the component.

4. Production phase

In the production phase, the activities during the pre-manufacturing caused by the introduction of composite are building molds, laminating pieces, deck part infusions and drilling. These activities require more time than that for traditional steel components. However, assembly of pre-manufactured composite pieces is faster than the classical welding. Additionally, steel structures require finishing work like blasting and painting, which are eliminated with use of composite, as they are free from corrosion and pigment coloration when used with resins.



Impact in Quality:

The impact on the quality rate is very difficult to judge, since the technology is relatively new in shipbuilding processes. In the first phases of using a new technology usually, more mistakes occur during the learning process. For the long term, the technology might have a positive or a negative impact on the quality rate.

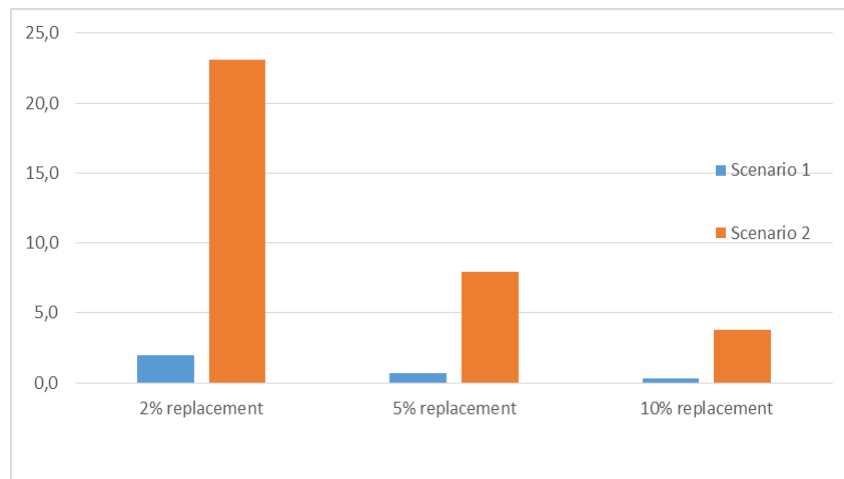


The technology has a positive impact on customer satisfaction due to multiple facts:

- Using composite materials allows the application of more complex shapes for the produced components than using steel due to the high flexibility of the moulds.
- Composite materials have different mechanical properties than steel and thus cannot replace steel in every aspect. However, they can be better suited for the components purpose if chosen with care.
- The weight reduction has positive consequences for the ships operational costs. It decreases fuel consumption, improves stability behaviours, decreases draft or allows an increased cargo capacity.
- The reduced weight and increased durability decrease maintenance and repair costs.
- The lead-time decreases and the schedule reliability improves leading to faster delivery times and compliance with deadlines.
- In addition, the reduced production costs could be passed on to the customer decreasing the price.

Return on Investment:

In the ROI calculation, the investment costs and running costs vary between the two aforementioned mentioned scenarios, as a shipyard which has to start from scratch to introduce composite production facility within their facility have to invest more in equipment, space and training, in comparison to a shipyard that can adapt its already existing facilities. The savings potential in introducing the composite in the ship structures vary on the level of introduction. Therefore, three further sub-scenarios of 2%, 5% and 10% replacement of existing steel ship components with new composite components have been assumed. For a Shipyard that is able to adapt its facility with new composite production facilities, the ROI ranges from 0,5 years to 2 years. For a Shipyard that has to investment more, due to its lack of adaptability, the ROI ranges from 3,8 years to 23 years.



It is to be noted, that in the ROI calculation, the possible fuel saving potential at the ship operational level due to the weight reduction in ship or the increased revenue possibility due to increased pay load at ship level due to the weight reduction in the ship, are not taken into consideration.

**Combined Impact of SMART technology in Shipyards' Shipbuilding Process**

Each technology and prototype has an impact on different processes in a shipyard. The impact of the individual SMART technologies varies a lot and that some processes are impacted by more than one technology.



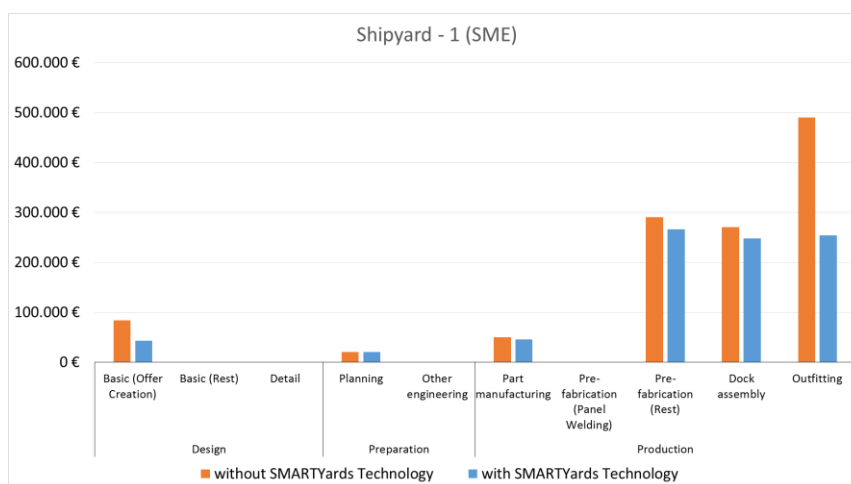


		Process					
		1	2	3	4	5	
		Offer creation	Design	Production planning	Panel welding	Repair + Outfitting	
Technology	1	Weight and Work Content Estimation	X				
	2	Distributed Design Process		X			
	3	Production Planning and Simulation			X	X	
	4	Micro Panel Line (Welding Robot)				X	
	5	Portable Container Workshop					X
	6	Composite Service Deck		X	X		X

To assess the total productivity impact by the SMART technologies, the influences of all technologies on every shipyard was assessed. Each of the Shipyard from the project, chose a Shipyard building project that represents their product portfolio and then analysed the impact on such a shipbuilding project while executing it with their existing technologies at the Shipyard and then made estimations if the same project was executed with the aid of the SMART technologies. The following phases were defined along with sub-phases, wherein it was identified there is an impact of the SMART technology when implemented,

- Design phase
  - Basic
  - Detail
- Preparation phase
  - Planning
  - Other engineering
- Production phase
  - Dock assembly
  - Outfitting

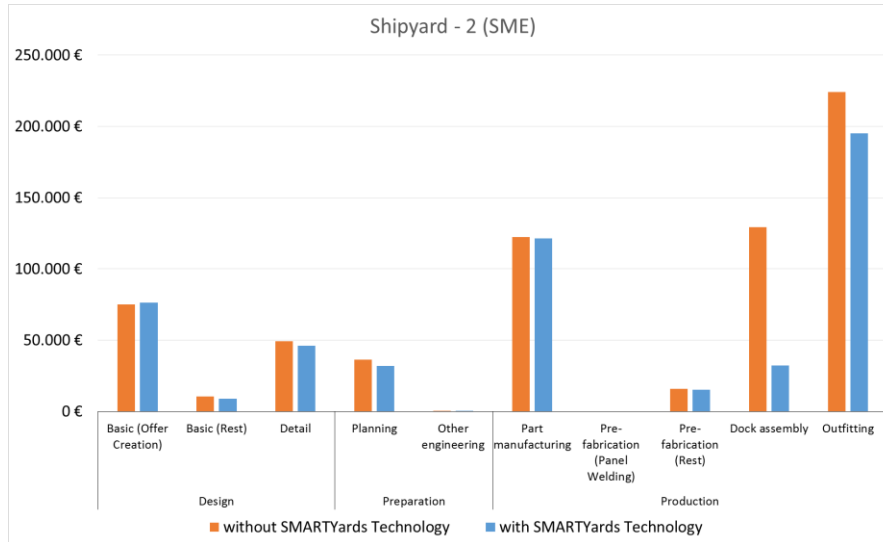
The figure below shows the result of the productivity assessment at a SME shipyard in SMARTYards with their main product portfolio includes Inland pushers. The main effects of cost reduction when applying the SMART technologies occur in the Production phase. Especially the outfitting process is an influential expense factor. The overall personnel cost reduction amounts in this case to 27.1 %. In this case, the assessment only considered internal processes as there do not arise outsourced activities



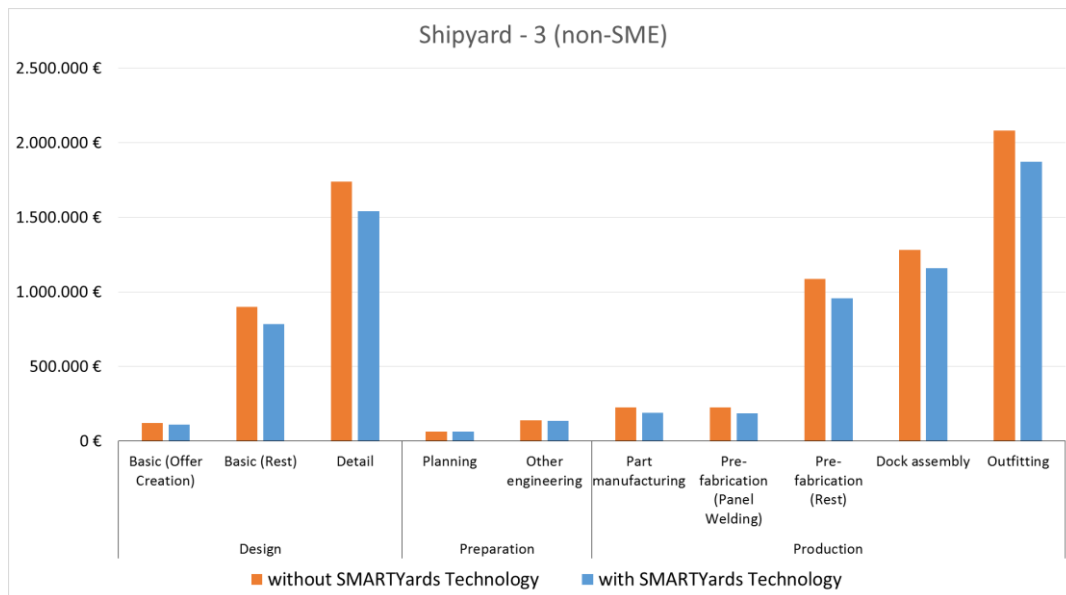
The next SME shipyard assessed have Fishing boats as their main product in their portfolio. The main effects of cost reduction when applying the SMART technologies occur in the Production phase, especially in the dock assembly process. The SMART technologies while implemented together in the shipyard can be de-



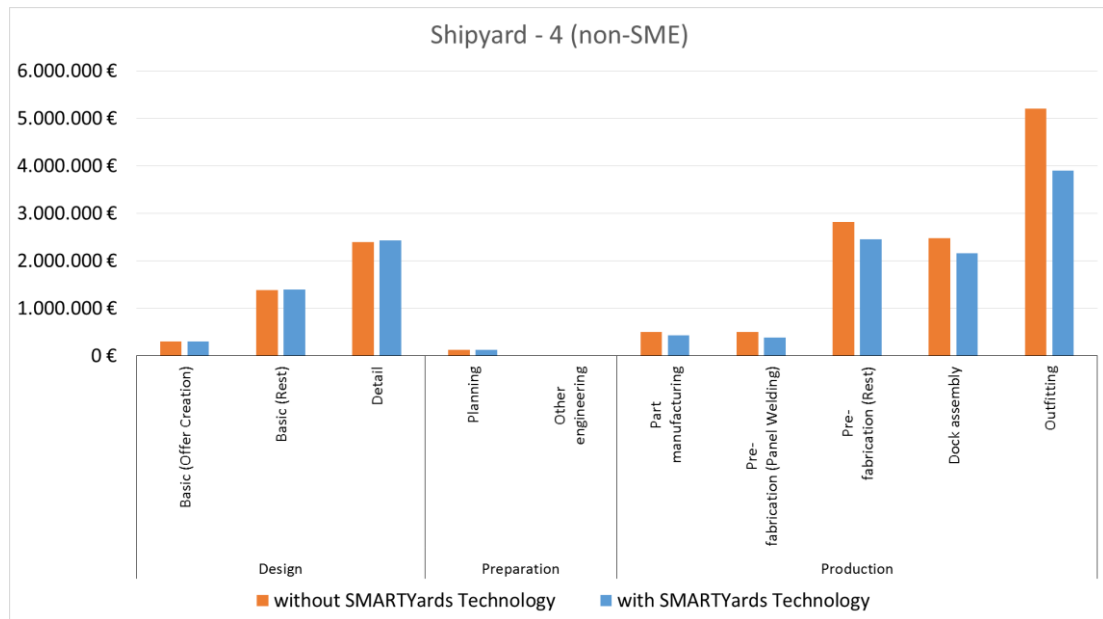
crease the dock assembly effort by about 70 %. The overall personnel cost reduction amounts in this case to 20.4 %. In this case, the assessment includes both internal and external processes.



The productivity assessment for a Ro-Pax vessel at a non-SME shipyard in the project is shown below. The main effects of cost reduction when applying the SMART technologies occur in the Design and in the Production phase. The overall personnel cost reduction is around 11 %. In this case, the assessment only considered internal processes as there do not arise outsourced activities in this project.



The fourth exemplary shipbuilding project was that of a RoPax vessel at another non-SME Shipyard. This shipyard have already advanced technologies in their facilities. In spite of it, it can be noted from the figure below, that there is an impact in the Production phase of this shipyard, while implementing the SMART technologies. This is mainly due to the introduction of Simulation in the Production Planning assessment. However, one can see that even for a bigger and technologically more advanced shipyard, the SMART technologies have a mentionable impact.





## 4.1.5 Relevant contact details

### 4.1.5.1 Coordinator contact

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### 4.1.5.1 Links

Project Website: [www.smartyards-project.eu](http://www.smartyards-project.eu)