

# ADDITIVE MANUFACTURING IN COMPLIANCE WITH LEAN SHIPBUILDING

Damir Kolich, Senior Assistant (PhD), University of Rijeka, Croatia

Richard Lee Storch, Professor (PhD) University of Washington, Seattle, WA,  
USA

Niksa Fafandjel, Professor (PhD) University of Rijeka, Croatia

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Sveučilište u Rijeci

COLLEGE OF ENGINEERING  
UNIVERSITY of WASHINGTON



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2. Lean shipbuilding
3. Additive manufacturing
4. Integration of additive and lean manufacturing
5. Conclusions

# Introduction

- Problem
  - Lean manufacturing in the automobile industry
  - Lean manufacturing in shipbuilding
  - Hyundai Corporation example
- Adapted for the shipbuilding industry

## LEAN MANUFACTURING

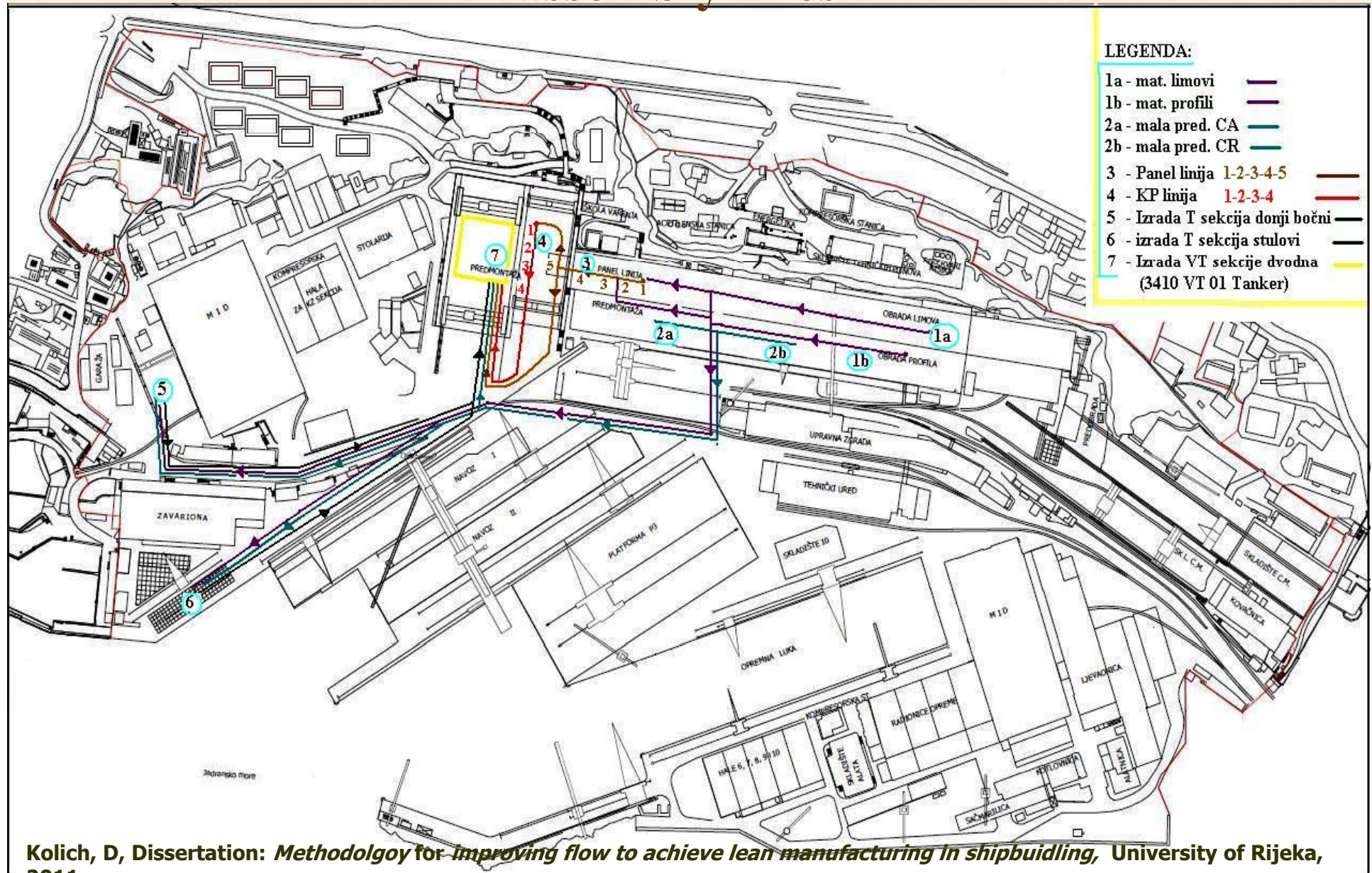


<http://www.dbckorea.com/lastevent.html>

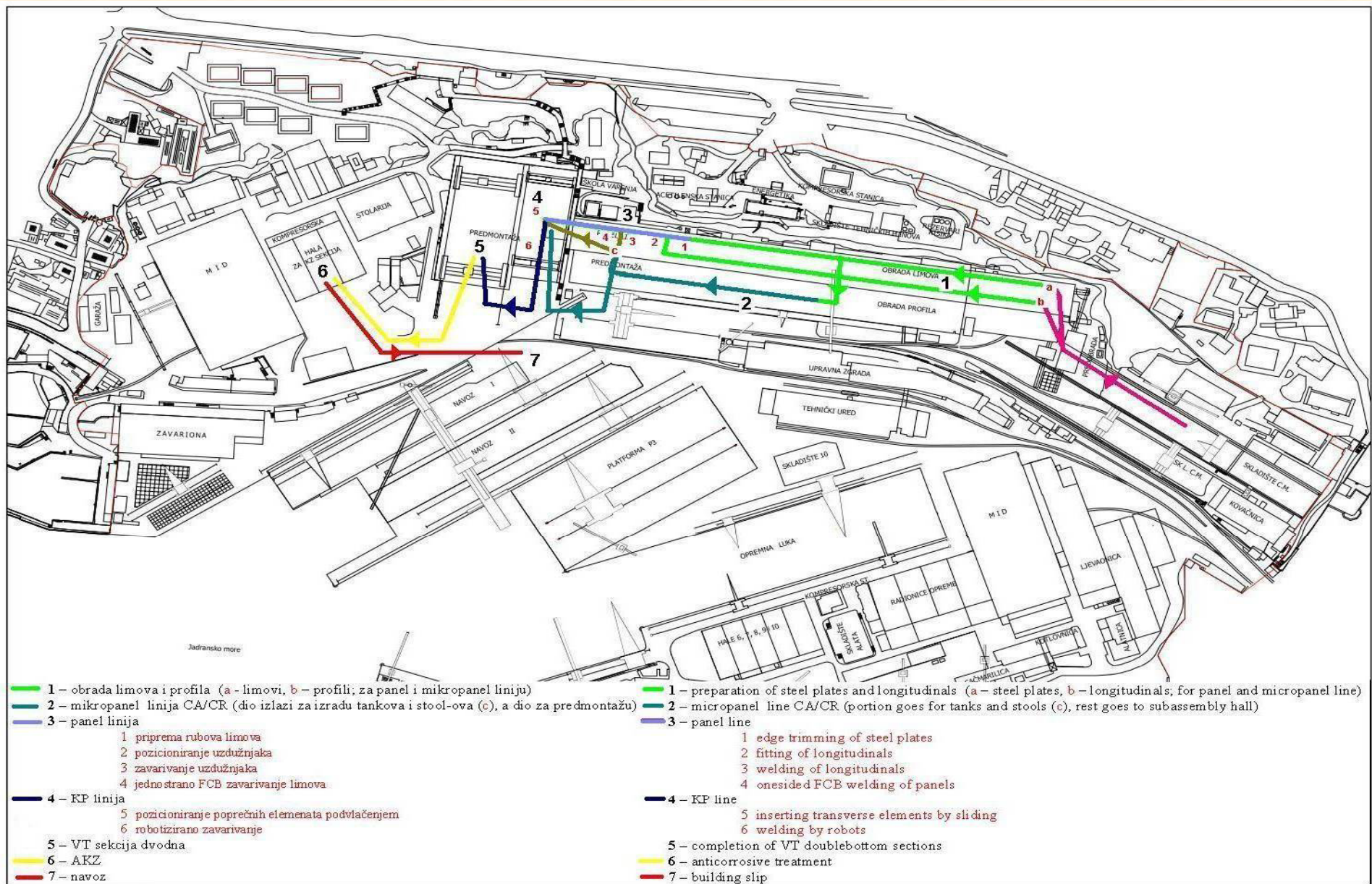


<http://in.reuters.com/article/2011/06/12/idINIndia-57648420110612>

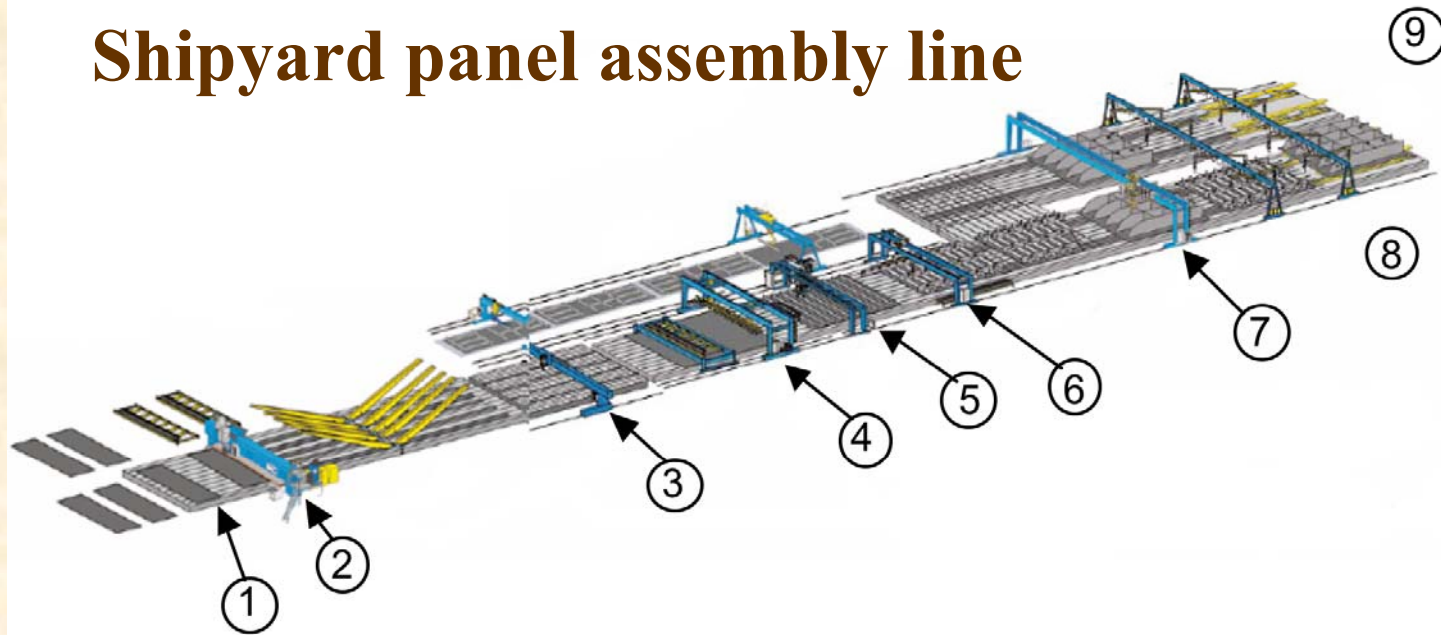
# Present shipyard configuration of interim product assembly lines



# Lean shipyard configuration of interim product assembly lines



## Shipyard panel assembly line



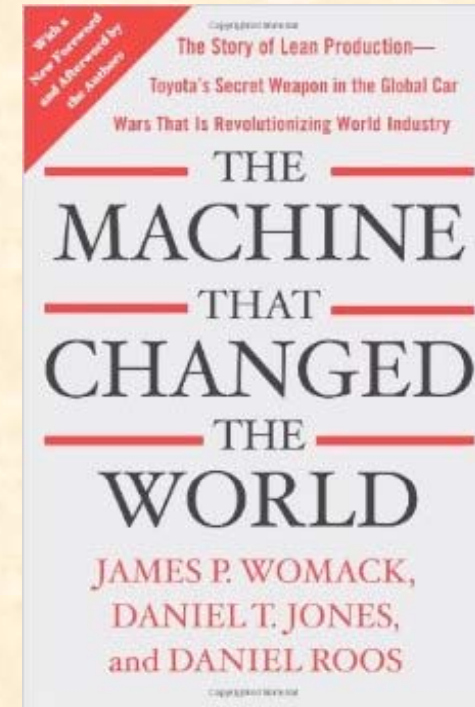
- 1) Panel assembly,
- 2) Panel welding,
- 3) Panel layout,
- 4) Longitudinal fitting,
- 5) Longitudinal welding,
- 6) Internal structure fitting,
- 7) Welding and outfitting of built-up unit,
- 8) Turning and fitting,
- 9) Welding and outfitting.

## 2. Principles of lean manufacturing

➤ A quarter of a century has passed since the publishing of the book

*The Machine That Changed the World*, authors Womack, Jones i Roos.

➤ This book derives from Toyota known as TPS: Toyota Production System



1. Specifying the product value from the customer's perspective,
2. Identifying the value stream,
3. Constant flow,
4. Pull,
5. Perfection or acceptable quality

## 2.1. Other principles of lean manufacturing

1. Just in Time and Built in quality,
2. 5S,
3. 7 wastes
4. Kaizen



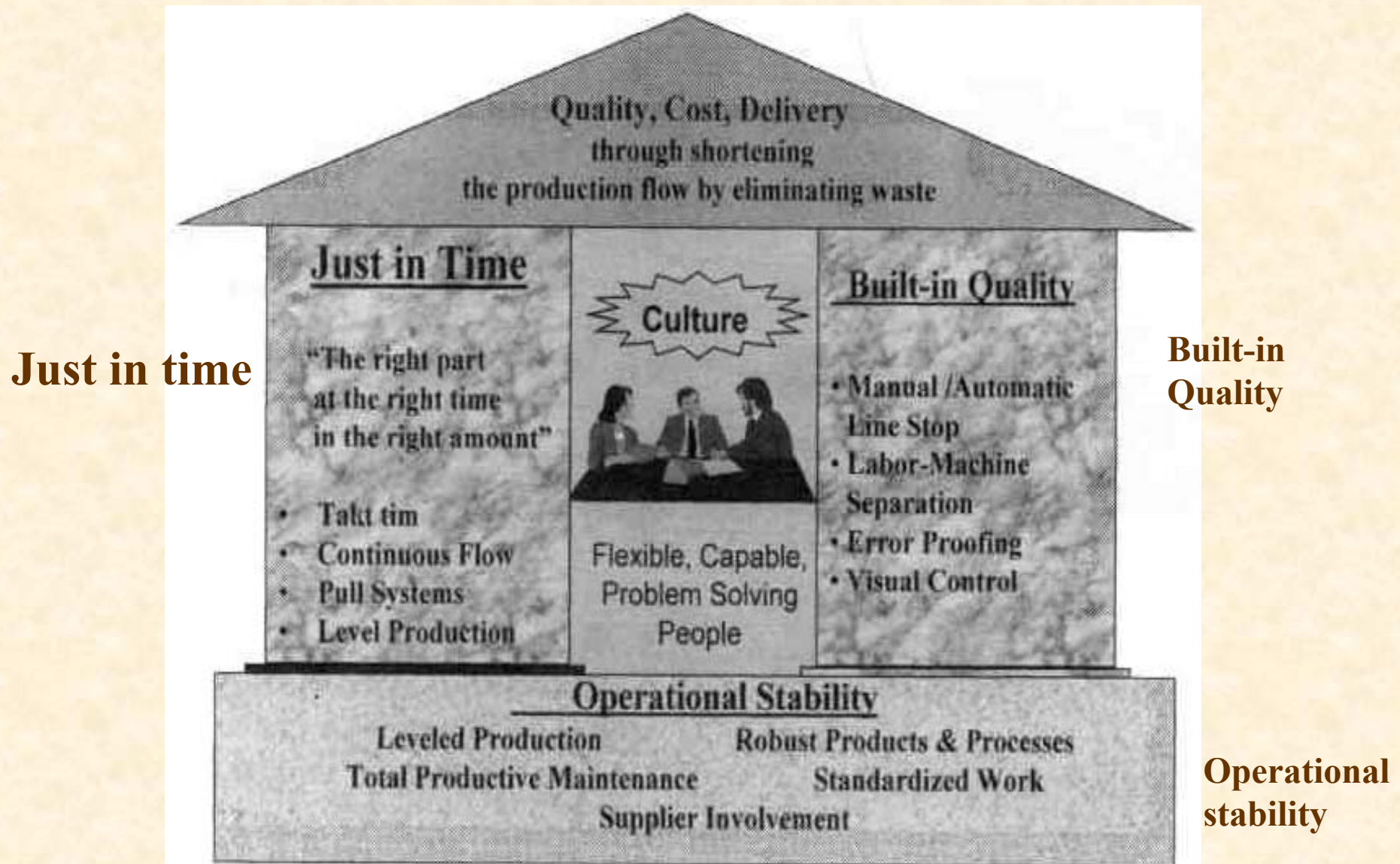
**Chemical tanker**



**Asphalt barge**

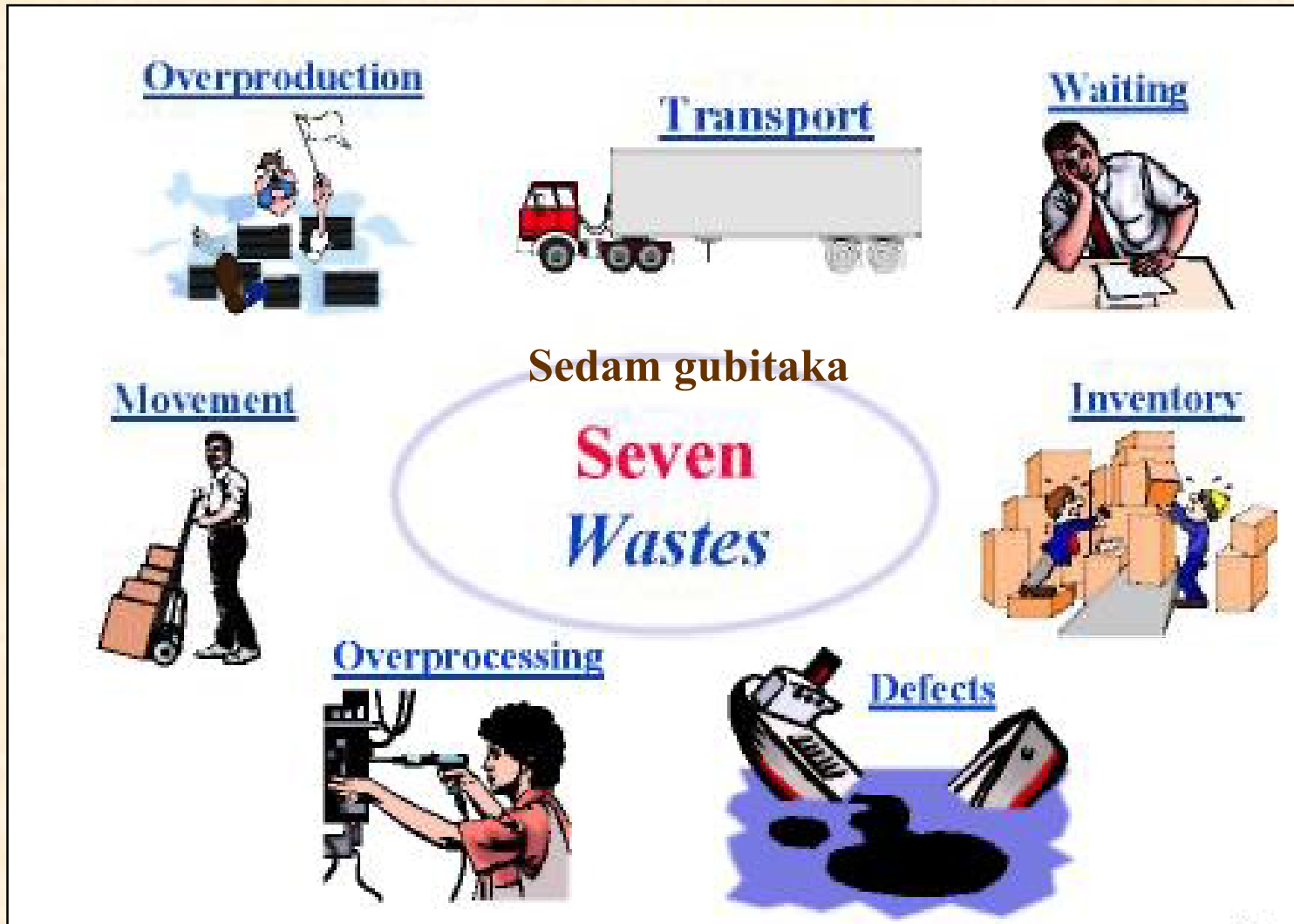


# Toyota production system



Liker, J.K., Lamb, T., *What is Lean Ship Construction and Repair?*,  
*Journal of Ship Production*, Vol. 18, No.3, 2002.

# 7 Wastes



Liker, J.K., Lamb, T., *What is Lean Ship Construction and Repair?*,  
*Journal of Ship Production*, Vol. 18, No.3, 2002.

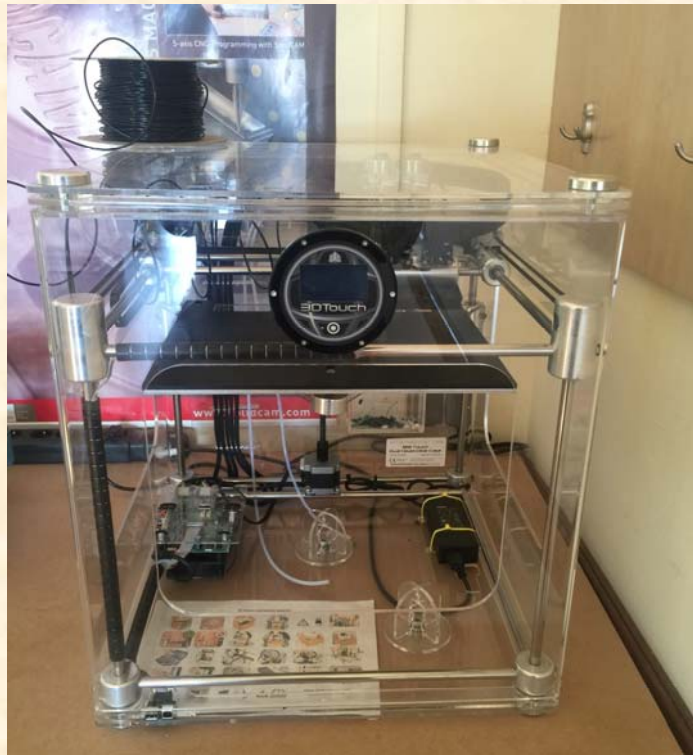
# 5 S



Liker, J.K., Lamb, T., *What is Lean Ship Construction and Repair?*,  
*Journal of Ship Production*, Vol. 18, No.3, 2002.

# 3.Additive manufacturing

- **Known as 3D printing**
- **3D printer adds layers upon layer**
- **Plastic polymer to build a solid object**
- **Cheaper/faster than tool and die on metals**



**University of Rijeka 3D printer, Student laborartory**

# Norfolk Naval Yard applications

- Used for making mockups
- Simple alterations/complex hull replacement
- Engineers and workers visualize
- Decreases risk during execution
- Decreases man-hours

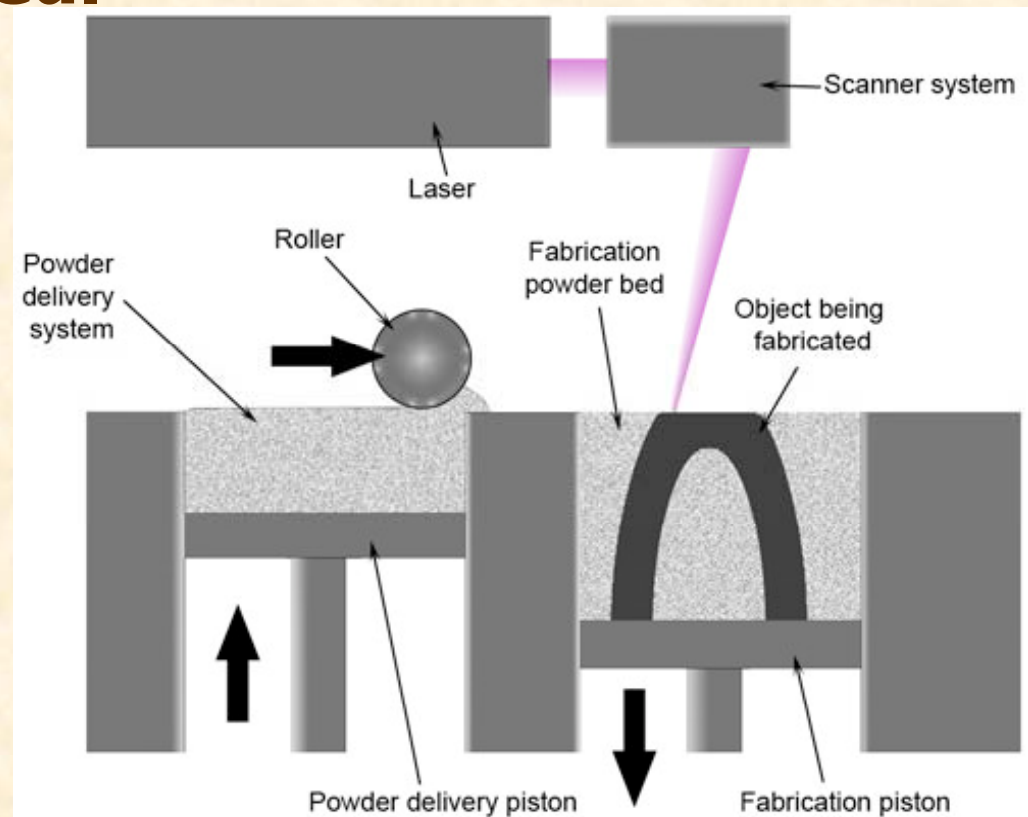


<http://navaltoday.com/2014/04/11/3d-printing-facilitates-norfolk-naval-shipyards-work-usa/>



# Direct Metal Laser Sintering

- Lasers are used to sinter powdered metal
- The laser uses 3D model data
- The material is compacted
- A solid mass is formed.
- 99% dense



# Companies that use DMLS

- **Stratasys - US**
- **Fonon Corporation - US**
- **EOS – Germany**
- **China Shipbuilding Industry Corporation**



[www.3Dprint.com](http://www.3Dprint.com)



FONON  
CORPORATION

[www.rapidreadytech.com](http://www.rapidreadytech.com)



[www.3Dprint.com](http://www.3Dprint.com)



e-Manufacturing Solutions

[www.rapidreadytech.com](http://www.rapidreadytech.com)

# **Additive manufacturing in compliance with lean**

- **Just in time and one piece flow**
- **For naval and maritime constructions,**
- **Manufacture one of a kind type steel part**
- **Without having to machine it.**
- **Or order it.**
- **Reduction in costs.**



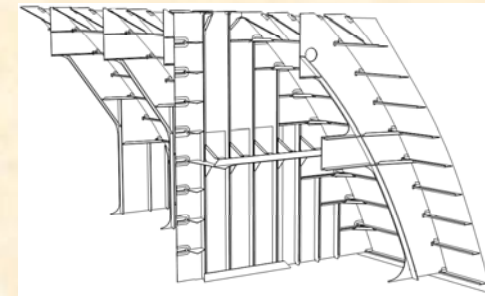
# Examples in manufacturing where there are applications

- One of a kind interim products
- Micropanel profile
- Non-standard brackets
- Outfitting equipment

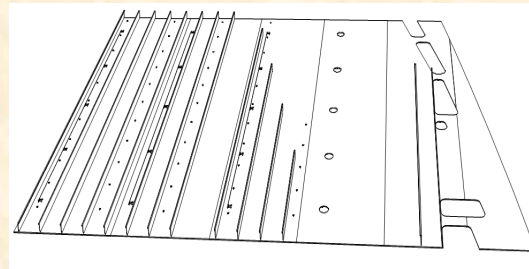


## ■ Double bottoms

## ■ Side shells - single and double skin



## ■ Decks



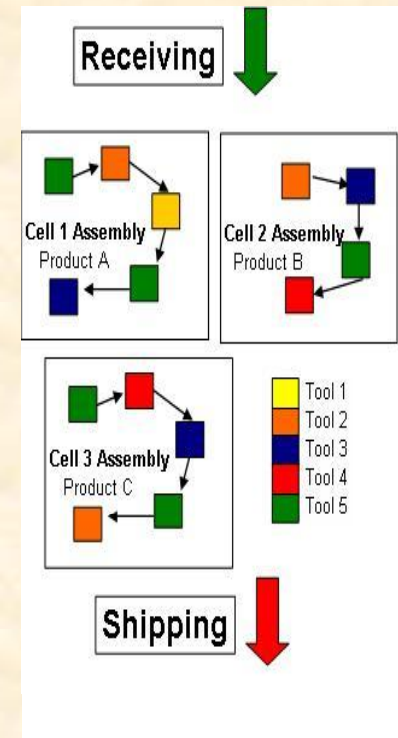
## ■ Longitudinal bulkheads



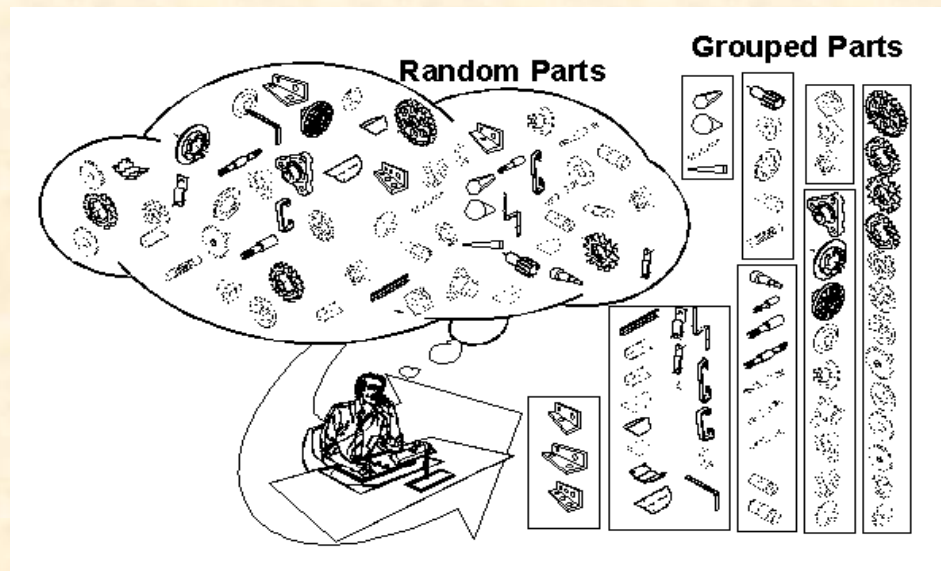
[Uljanik Shipyard, 2009.]

# Increasing lean manufacturing application in shipbuilding

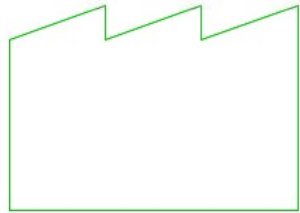
- Smaller and complex parts
- That is expensive to order
- Could be quickly manufactured
- Using Additive manufacturing



<http://www.nwlean.net/article1103.htm>



## Value Stream Mapping Legend

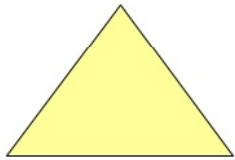


Supplier/Customer

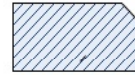


Physical pull

Non-value added process
Takt time
C/T = changeover time
# operators:
# plates/shift
man-hrs



Interim storage



Withdrawal kanban



Push arrow



Supermarket



Manual information



Kanban post

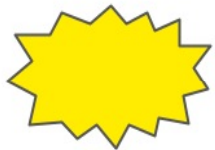


Electronic information



Kanban pull signal

Added value process
Takt time
C/T = changeover time
# operators:
# plates/shift
man-hrs

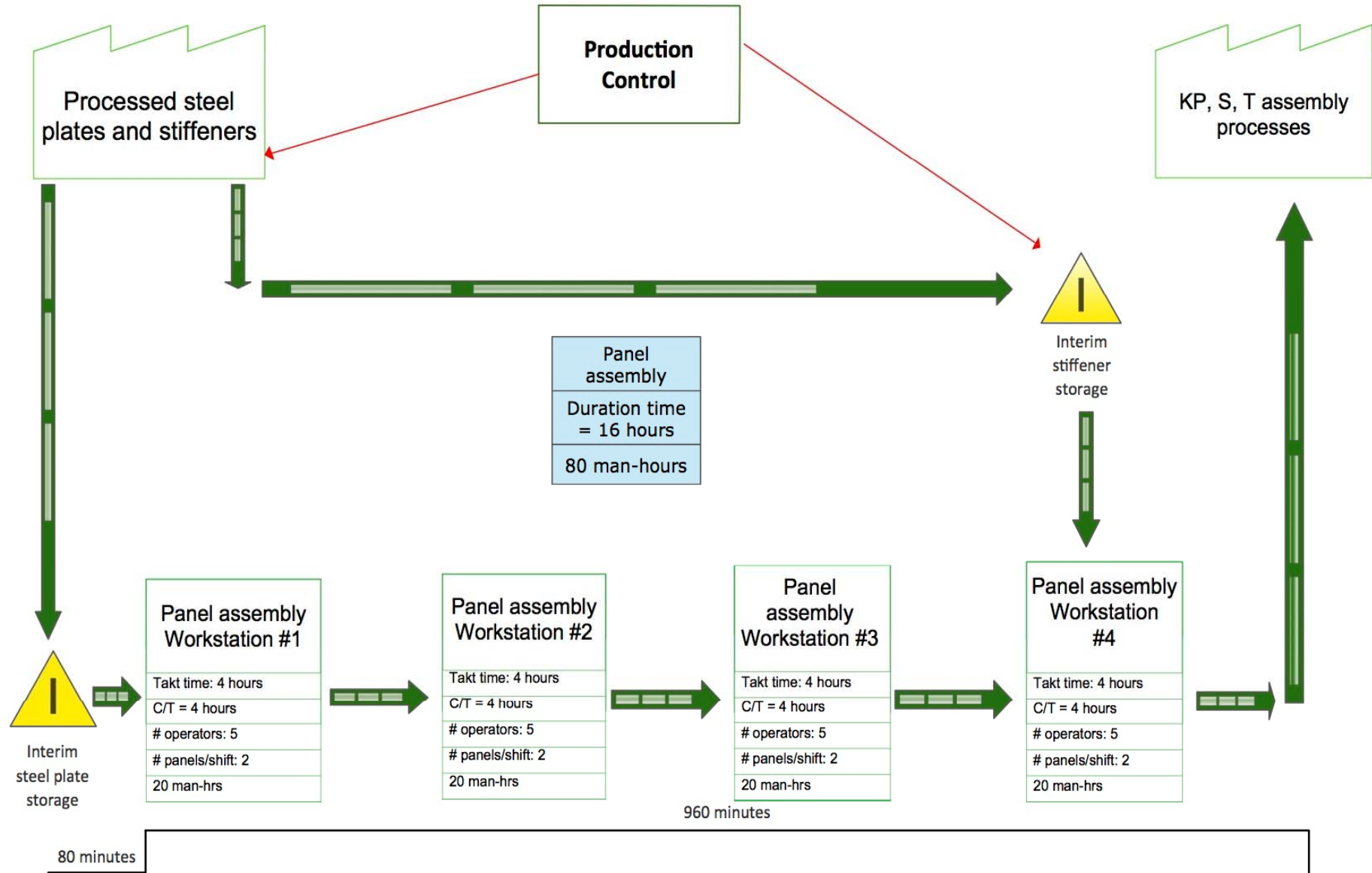


Improvement burst

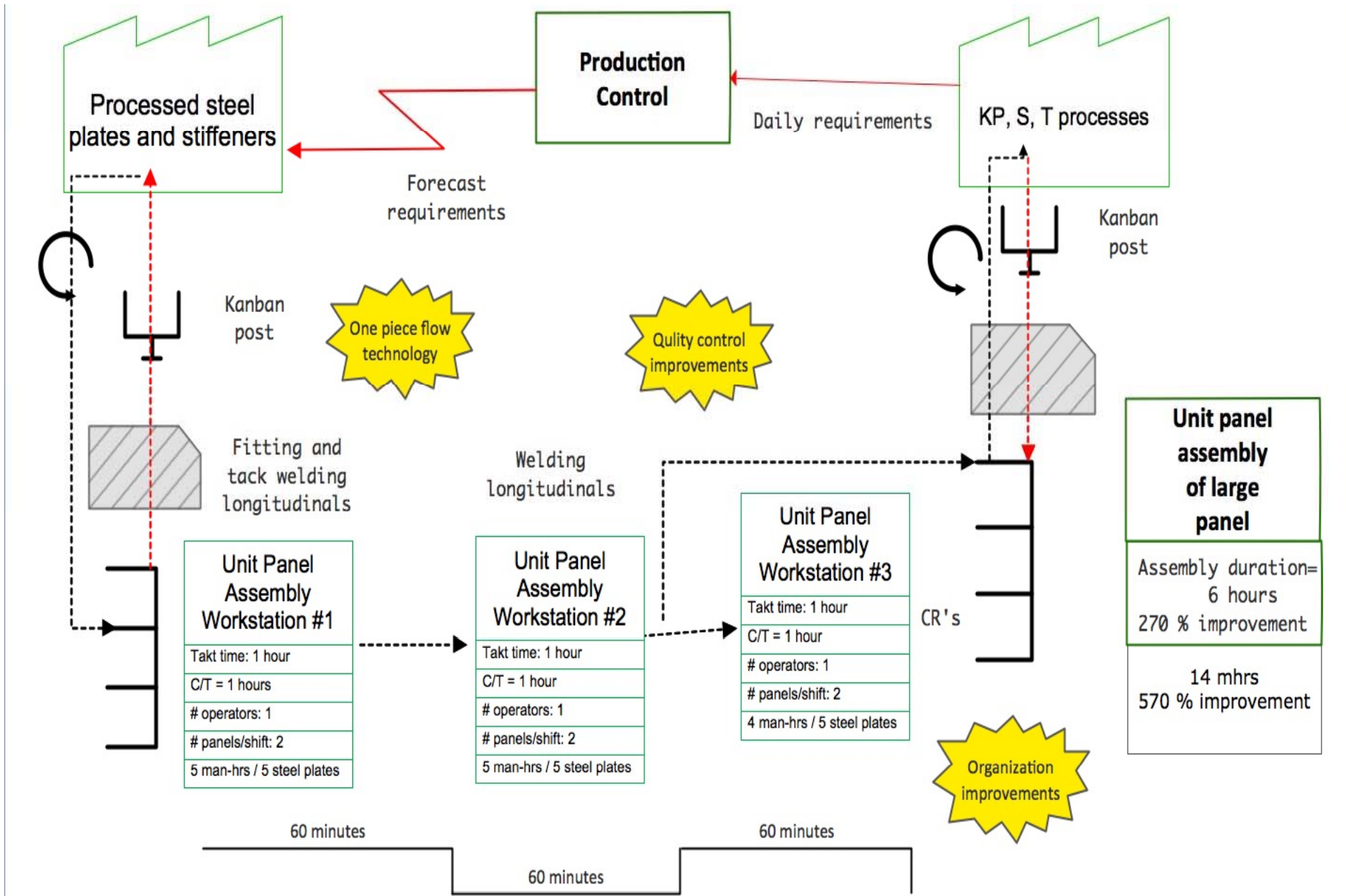


Pull arrow

# Value stream map – Current state

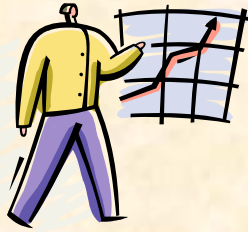


Kolich, D., Storch, R.L., Fafandjel, N.: Optimizing Shipyard Interim Product Assembly Using a Value Stream Mapping, World Maritime Technology Conference 2015, Ship Production Symposium, p.1-10, WMTC 2015, 03. – 07. 11. 2015., Providence, Rhode Island, USA.



# Value Stream Map - Future

# Conclusions



- **Additive manufacturing complements**
- **Lean shipbuilding well**
- **Entices one-piece flow**
- **Decreases transport, waiting and storage**
- **Decreases man-hours and duration time**
- **Significant savings**



**Thank you for your attention!**