University of Padova
Department of Management and Engineering

THE AGEING WORKFORCE PROBLEM IN EUROPEAN INDUSTRIAL SYSTEMS: DECISION SUPPORT MODEL AND THE TRADE-OFF ANALYSIS

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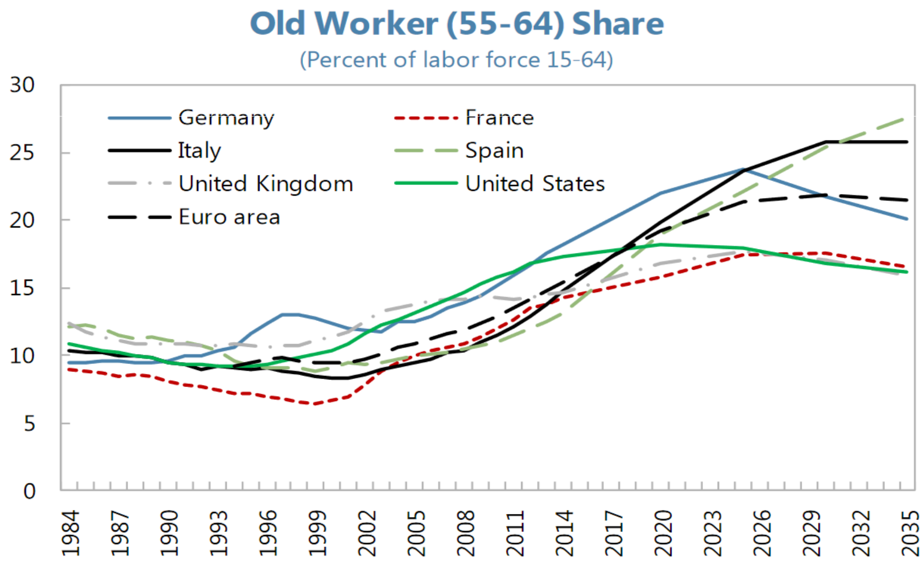
Outline

1. Problem statement and scope
2. The case study
3. Human resources in the extended MRP model
4. The costs of human resources and collaborative robots, influencing NPV
5. Conclusions and next steps

Problem statement and scope

- **EU population is aging**
- **Sustainable pension system: the retirement age of industrial workers is rising in many EU countries (ITALY: 67 years from 2019)**
- **Ageing workers in industrial tasks:**
  - ➢ **expert craftsmen**
  - ➢ **not substitutable by robots (versatility, adaptability, flexibility)**
  - ➢ **decrease in physical and cognitive capabilities**
  - ➢ **higher risk of injuries**
  - ➢ **decrease in productivity**



Sources: OECD; European Commission; BLS; and IMF staff calculations.

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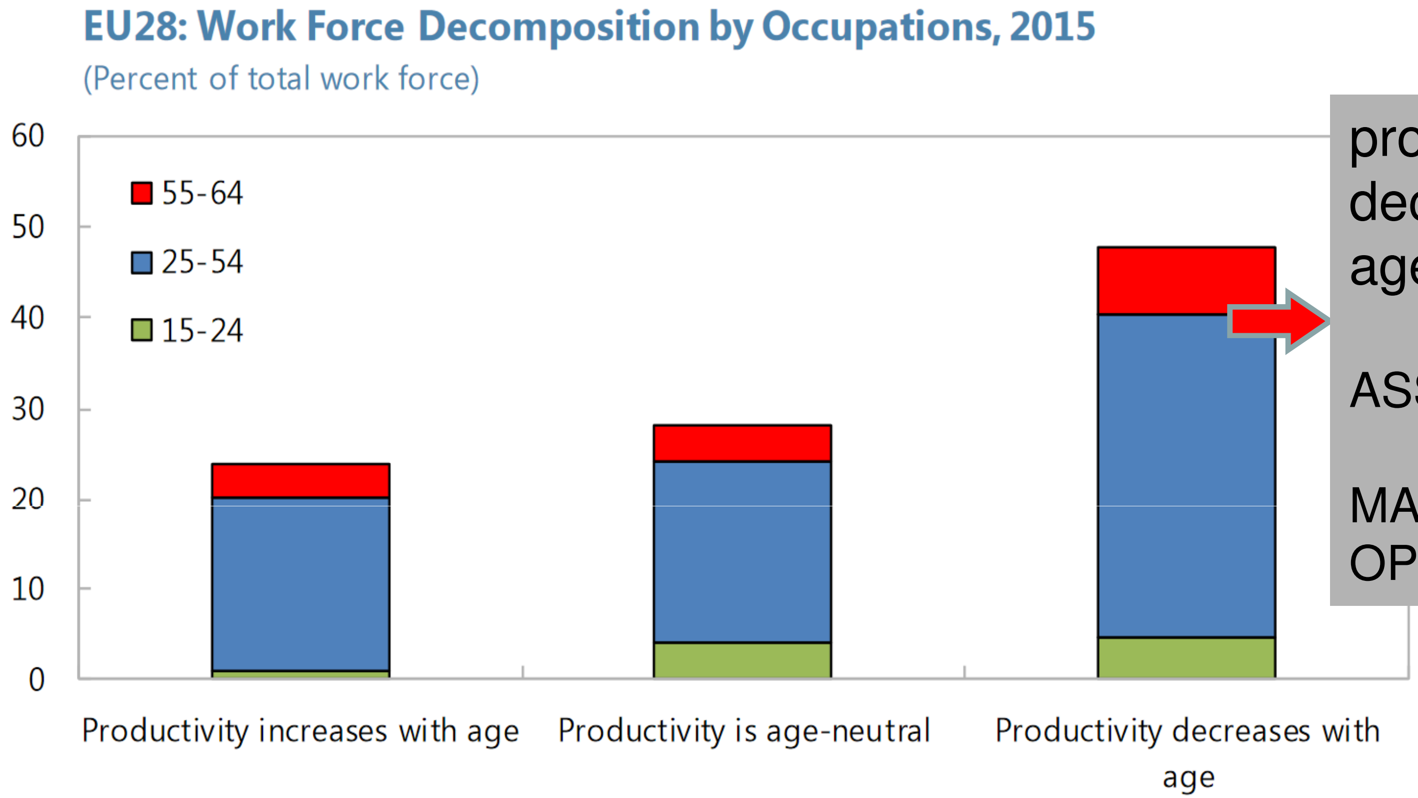
Problem statement and scope



productivity decreases with age for:

ASSEMBLERS

MACHINE/PLANT OPERATORS

Note: Category "...increase with age" includes: managers, and professionals; Category "...age-neutral" includes: clerical support workers and services and sales workers; Category "...decrease with age" includes: technicians, skilled agricultural, forestry and fishery workers, craft and related trades workers, plant and machine operators and assemblers, elementary occupations and armed forces occupations.

Sources: Venn (2008); Eurostat; and IMF staff calculations.

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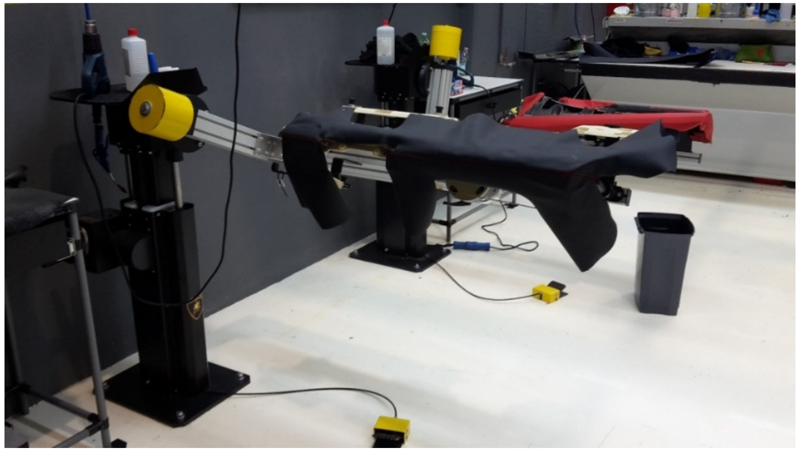
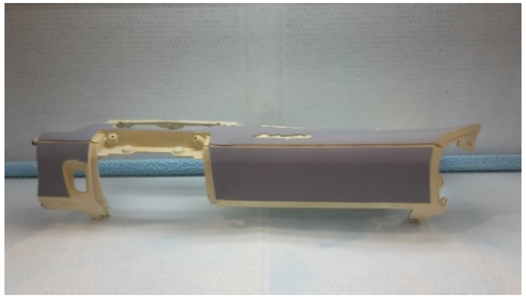
Problem statement and scope

A recent Italian example:

- Italian producer of sportive car
- highly personalized interiors
- Ageing expert workers

Collaborative Robots in the saddlery dept. to increase the efficiency of the glowing process and assist workers during non-ergonomic tasks.





Problem statement and scope

THE AIM OF A COMPANY: preserving productivity

3 MOVE a part of production to other countries (Eastern)- adding transportation

1 ACCELARATE the internal turnover by early retirement

2 INVEST in Assistive Technologies

This work

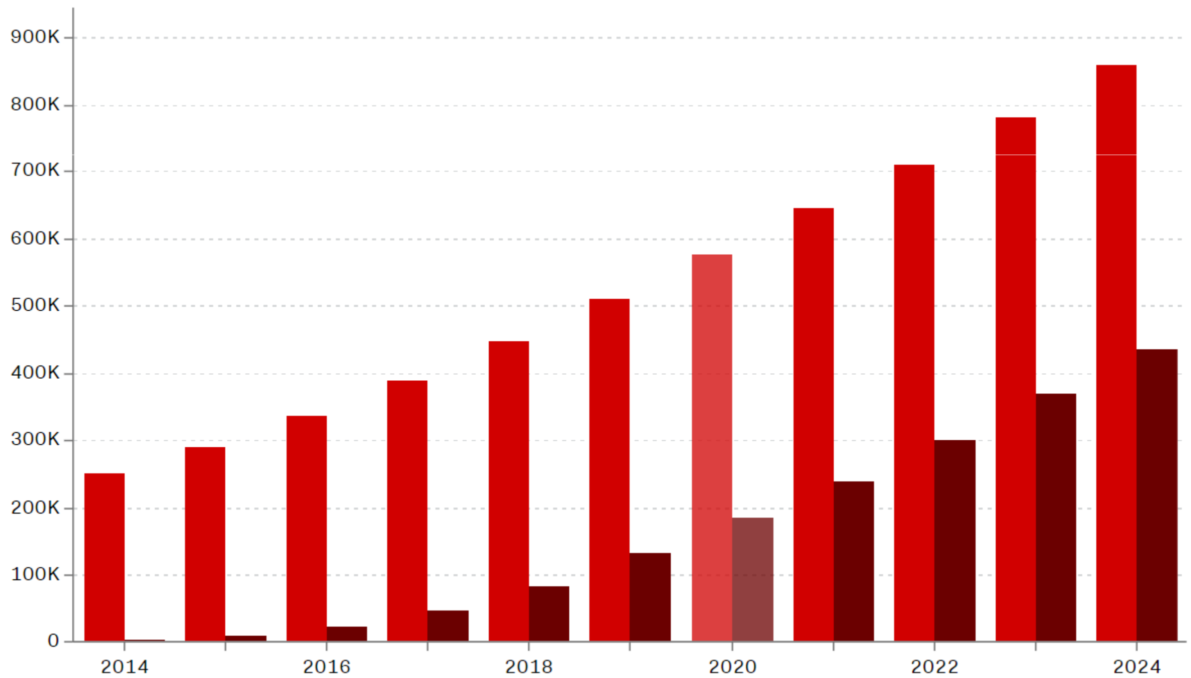
Actuarial Present Value dimension of Optimization, APV

Problem statement and scope:

Traditional versus collaborative robots

In 2016, collaborative robots only represented 3 percent of industrial robots sold.

Traditional versus collaborative industrial robots in units sold



Source: Loup Ventures 2017

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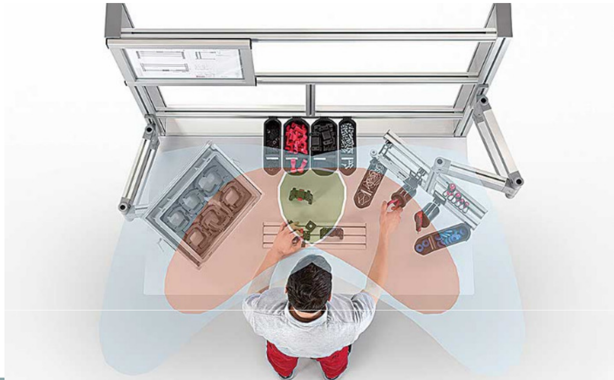
asb0517Workstation1.jpg

Outline

***RESEARCH QUESTION:** Invest or not to invest in an ergonomic environment capable to reduce workforce fatigue ageing-friendly?*



Collaborative robots (COBOTS)	Industrial Exoskeletons	Smart workstations

We develop a model based on MRP Theory to evaluate both options:

- Early retirement and movement of activities in Eastern countries or
- investment in Assistive Technologies and smart work-space;
- Actuarial Present Value has been included to NPV for measuring early retirement products (> cash flows).

Outline

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The case study

An Italian manufacturer of water pumps has two options:

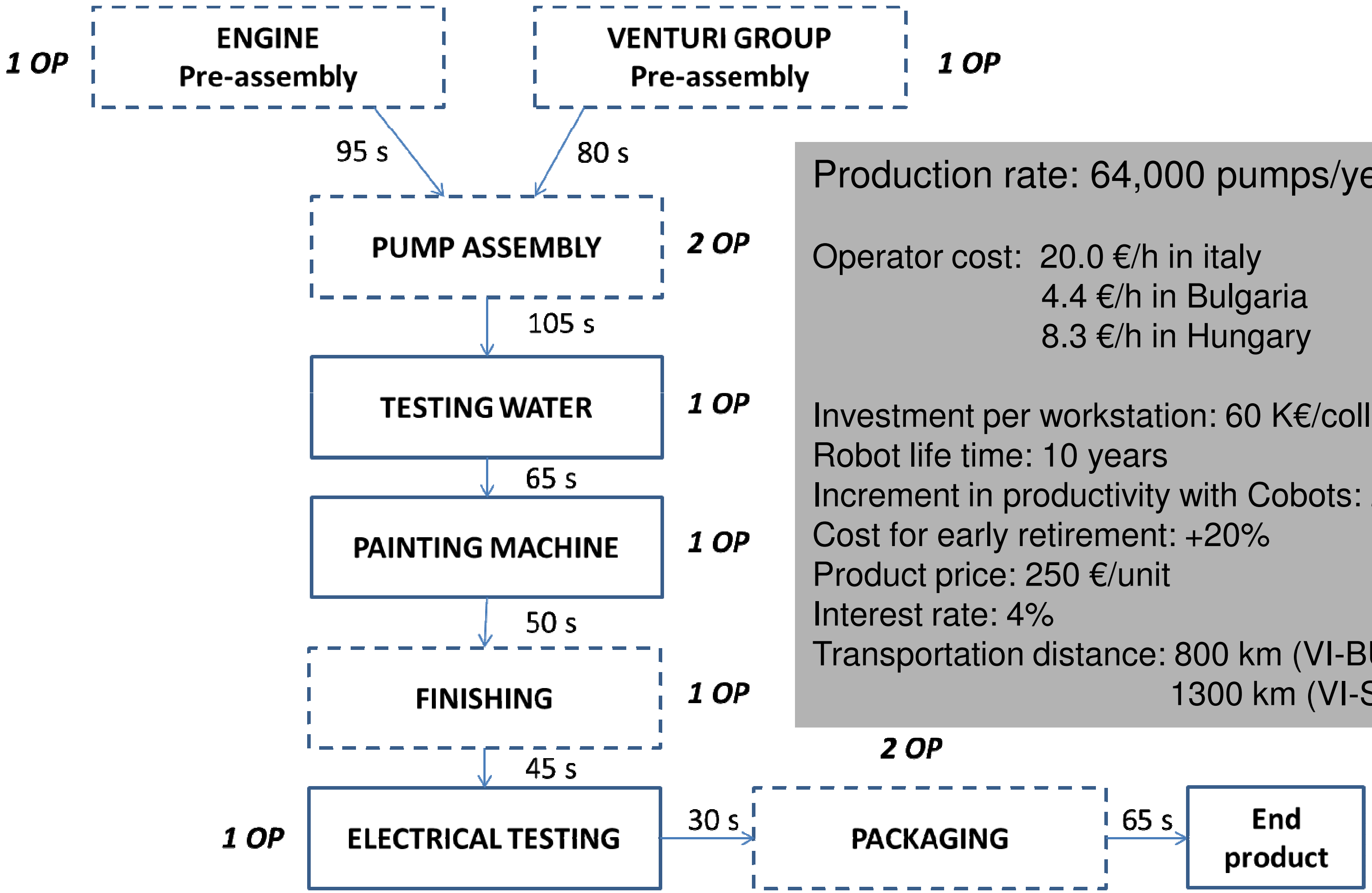
(a) to buy assistive technologies and better involve highly skilled ageing workers

(b) to retire them earlier, to pay in early retirement schemes and to outsource production to suppliers or keep in existing production plants.

#2 OUTSOURCING OPTIONS and transportation costs:

- Supplier in Hungary (close to Budapest: 11 hours distance)
- Supplier in Bulgaria (close to Sofia: 17 hours distance)

The case study



Production rate: 64,000 pumps/year

Operator cost: 20.0 €/h in italy
4.4 €/h in Bulgaria
8.3 €/h in Hungary

Investment per workstation: 60 K€/collaborative robot
Robot life time: 10 years
Increment in productivity with Cobots: 20%
Cost for early retirement: +20%
Product price: 250 €/unit
Interest rate: 4%
Transportation distance: 800 km (VI-BUD)
1300 km (VI-SOFIA)

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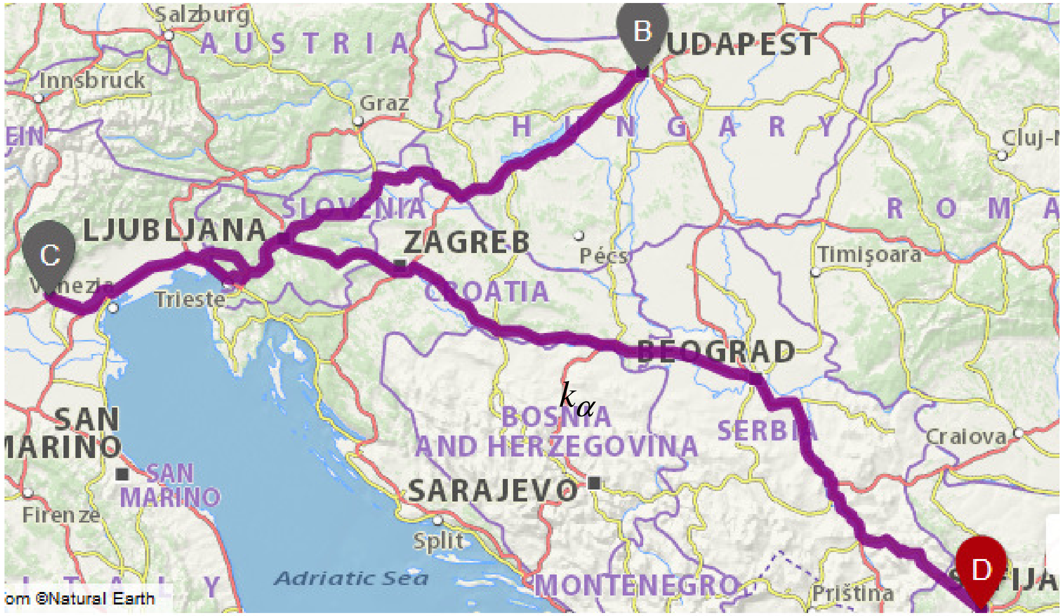
The case study



[EUR]	Labour costs Hourly	Labour costs Yearly	
Italy	20.00	38,400	
Hungary	8.30	15,936	
Bulgaria	4.40	8,448	

Distance		Transport Price/km	Transport/ truck	Pcs/ load unit	Load units/ Truck	pcs/ truck	transport/ pcs
	km	EUR	EUR			EUR	EUR
Vicenza – Budapest	800	1.2	1560	80	33	2640	0.59
Vicenza – Sofia	1300	1.2	960	80	33	2640	0.36

Definition

The term "age management" may refer specifically to the various dimensions by which human resources are managed within organisations with an explicit focus on aging and, also, more generally to the overall management of workforce ageing via public policy or collective bargaining (Walker, 2005).

There are five main dimensions of age management in organisations:

-job recruitment (and exit);
-training, development and promotion;
-working practices;
-ergonomics and job design; and
-changing attitudes towards ageing workers.

BOGATAJ, David, VODOPIVEC, Robert, BOGATAJ, Marija. **Dynamic decision model for superannuation of industrial workers** : David Bogataj, Robert Vodopivec, Marija Bogataj. V: GRUBBSTRÖM, Robert W. (ur.), HINTERHUBER, Hans H. (ur.). Seventeenth international working seminar on production economics, Innsbruck, 20-24 Feb. 2012, (Pre-prints, Vol. 1). Innsbruck: Congress Innsbruck. 2012, pp. 25-31.

BOGATAJ, David, VODOPIVEC, Robert, BOGATAJ, Marija. **The extended MRP model for the evaluation and financing of superannuation schemes in a supply chain. Technological and economic development of economy**, ISSN 2029-4913. [Print ed.], 2013, vol. 19, suppl. 1, str. S119-S133, ilustr., doi: 10.3846/20294913.2013.875957.

BOGATAJ, Marija, BOGATAJ, David. **Optimal retirement age and related database for the transportation industry workers**. V: PAWAR, Kulwant S (ur.), POTTER, Andrew (ur.), LISEC, Andrej (ur.). Data driven supply chains : The proceedings of 22nd International Symposium on Logistics, Ljubljana, Slovenia, 9-12th July 2017. Nottingham: Business School. cop. 2017, str. 417-424. http://www.isl21.org/wp-content/uploads/2017/07/Full-paper-31072017.pdf.

BOGATAJ, David, BOGATAJ, Marija. **Age management of human resources**. V: ZADNIK STIRN, Lidija (ur.), et al. SOR '17 proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research. 2017, str. 235-241.

Daria Battini, Martina Calzavara, Fabio Sgarbossa and Alessandro Persona, David, BOGATAJ, Marija. **MRP Theory Supporting Trade-off Between Investments in Collaborative Robots and Production In Foreign Countries for a Water Pumps Supply Chains**. V: ZADNIK STIRN, Lidija (ur.), et al. SOR '17 proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research. 2017, str. 235-241

The Objective:

To find the fair actuarial value and sustainability in production plans

c_L:cost of work per worker per time payed to worker + taxes; α_R - percentage on cost of work payed in pension schemes; α_H - health care; α_E- ergonomics

The present value of profits should be nonnegative:

$$\sum_{i=1}^{n} c_{L,i}\left(1+\alpha_{Ri}+\alpha_{Hi}+\alpha_{Li}+\alpha_{Ei}\right)L_i\tilde{x}_i(\rho) \le NPV_{tot}$$

Actuarial analysis

Bogataj et all.

Ergonomics

Battini, Persona ell.

MRP Theory

Grubbström et all.

The basic extended MRP model

Generalised transportation-production-input matrix

(from Grubbström, 2007, Bogataj et al. 2007, Bogataj and Grubbström,2013)

$$\breve{\mathbf{H}}'(s) = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ h_{21}e^{s\tau_{21}(1+\delta_{21})} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_{n1}e^{s\tau_{n1}(1+\delta_{n1})} & h_{n2}e^{s\tau_{n2}(1+\delta_{n2})} & \cdots & 0 \end{bmatrix} \begin{bmatrix} e^{s\tau_1(1+\delta_{\tau 1})} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e^{s\tau_n(1+\delta_{\tau n})} \end{bmatrix}$$

Transportation delays and their perturbations

Production delays and their perturbations

The basic extended MRP model-

Net production

The requirements for the production plan $\tilde{\mathbf{P}}(s)$
written as $\breve{\mathbf{H}}'(s)\tilde{\mathbf{P}}(s)$
are specified in the frequency domain where the net production $\tilde{\mathbf{x}}(s)$
will conveniently be written as follows:

$$\tilde{\mathbf{x}}(s) = (\mathbf{I} - \breve{\mathbf{H}}'(s))\tilde{\mathbf{P}}(s)$$

Net production

generalised transportation-production-input matrix –depends on productivity of workforce ➡ on aging

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The basic extended MRP model-

Production vector in frequency domain *s*

For cyclical processes, the requirements for the production plan:

$$\tilde{\mathbf{P}}(s) = \tilde{\mathbf{t}}'(s)\tilde{\Gamma}'(s)\hat{\mathbf{P}} = diag\left(e^{\frac{-st_1(1+\sigma_1)}{1-e^{-s(\Gamma_1+\Delta\Gamma_1)}}}, \ldots, e^{\frac{-st_n(1+\sigma_n)}{1-e^{-s(\Gamma n+\Delta\Gamma_n)}}}\right) \cdot \hat{\mathbf{P}}$$

perturbed matrix of starting moments of activities

Perturbed total cycle

Production intensity

Human resources in the extended MRP model

Ageing and ergonomics in this model influence:

- perturbed production intensity

$$\tilde{\mathbf{P}}(s) = \left[\frac{e^{-st_1(1+\sigma_1)}\hat{P}_1}{1-e^{-s(\Gamma_1+\Delta\Gamma_1)}} \quad \cdots \quad \frac{e^{-st_n(1+\sigma_n)}\hat{P}_n}{1-e^{-s(\Gamma_n+\Delta\Gamma_n)}} \right]^T$$

- generalised transportation- production-input matrix

$$\mathbf{H}'(s, \delta_{ij}, \delta_{\tau i})$$

- quality of production and consequently the prices:

$$\mathbf{p} = \mathbf{p}^1 + \Delta\mathbf{p} = \left[p_1^1(1+\delta_1), p_2^1(1+\delta_2), \dots, p_n^1(1+\delta_n) \right]$$

Perturbation of prices according to different products' quality

- **All these perturbations influence NPV**

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NPV of production and transportation

According to the *Net Present Value Theorem*, the NPV of the cash flow is obtained by replacing the complex frequency *s* with the continuous interest rate ρ, for example

- for NPV of production NPV_{prod},
- ordering and fix costs per cycle NPV_{ord}, and
- transportation NPV_{tr}:

$$\mathrm{NPV}_{tot} = \mathrm{NPV}_{prod} - NPV_{ord} - NPV_{tr} = \sum_{i=1}^{n} \Big(p_i \, (1+\delta_i) \Big) \tilde{x}_i(\rho) -$$

$$- \left\{ \frac{\mathbf{K} + \mathbf{E}^T \mathbf{\Pi}}{\rho} \right\} \left[\frac{e^{-(\rho) t_1 (1+\sigma_1)} \hat{P}_1}{\Gamma_1 + \Delta\Gamma_1} \quad \cdots \quad \frac{e^{-(\rho) t_n (1+\sigma_n)} \hat{P}_n}{\Gamma_n + \Delta\Gamma_n} \right]^T$$

Setup vector

Transportation matrix

PERTURBATIONS IN TRANSPORTATION

Changes in cost of transport per item per time unit

Delays in transportation time

$$\mathbf{\Pi}_{perturbed} = \begin{bmatrix} 0 & \cdots & & & \\ h_{21}(b'_{21}+c_{21})(\tau_{21}+\Delta\tau_{21}) & \cdots & \cdots & \cdots & 0 \\ \cdots\cdots\cdots & h_{ij}(b'_{ij}+c_{ij})(\tau_{ij}+\Delta\tau_{ij}) & \cdots & \cdots & 0 \\ \cdots\cdots\cdots & \cdots & \cdots & \cdots & 0 \\ h_{n1}(b'_{n1}+c_{n1})(\tau_{n1}+\Delta\tau_{n1}) & h_{nj}(b'_{nj}+c_{nj})(\tau_{nj}+\Delta\tau_{nj}) & \cdots & \cdots & 0 \end{bmatrix}$$

$$\mathrm{NPV}_{tot} = \mathrm{NPV}_{prod} - NPV_{ord} - NPV_{tr} = \sum_{i=1}^{n}\Big(p_i\,(1+\delta_i)\Big)\tilde{x}_i(\rho) -$$

$$-\left\{\frac{\mathbf{K}+\mathbf{E}^T\mathbf{\Pi}}{\rho}\right\}\left[\frac{e^{-(\rho)t_1(1+\sigma_1)}\hat{P}_1}{\Gamma_1+\Delta\Gamma_1} \quad \cdots \quad \frac{e^{-(\rho)t_n(1+\sigma_n)}\hat{P}_n}{\Gamma_n+\Delta\Gamma_n}\right]^T$$

Setup vector

Transportation matrix- could be perturbed

INVESTMENTS EXPRESSION

$$\mathrm{NPV}_{profit} = \mathrm{NPV}_{tot} - NPV_I - NPV_{hr}$$

Example :

$\Rightarrow$ **Periodical(yearly)I** : $NPV_I = I / \rho$

Additional investments in ergonomics

$\Rightarrow$ **Distributed to workplaces** : $NPV_I = \frac{1}{\rho}\sum_{i=1}^{n} c_{L,i}\alpha_{E,i}L_i \frac{e^{-(\rho)t_i(1+\sigma_i)}\hat{P}_i}{\Gamma_i + \Delta\Gamma_i}$

$$NPV_{hr} = \frac{1}{\rho}\sum_{i=1}^{n} c_{L,i}\cdot L_i \frac{e^{-(\rho)t_i(1+\sigma_i)}\hat{P}_i}{\Gamma_i + \Delta\Gamma_i}$$

EXPRESSION SHOULD enable to compare with costs of human resources

$$\mathrm{NPV}_{profit} = \mathrm{NPV}_{tot} - NPV_I - NPV_{hr} = \sum_{i=1}^{n}\left(p_i\,(1+\delta_i)\right)\tilde{x}_i(\rho) - \left\{\frac{\mathbf{K} + \mathbf{E}^T\mathbf{\Pi}}{\rho}\right\} \left[\frac{e^{-(\rho)t_1(1+\sigma_1)}\hat{P}_1}{\Gamma_1 + \Delta\Gamma_1} \quad \dots \quad \frac{e^{-(\rho)t_n(1+\sigma_n)}\hat{P}_n}{\Gamma_n + \Delta\Gamma_n}\right]^T - \frac{1}{\rho}\sum_{i=1}^{n} c_{L,i}(1+\alpha_{E,i})L_i \frac{e^{-(\rho)t_i(1+\sigma_i)}\hat{P}_i}{\Gamma_i + \Delta\Gamma_i}$$

The optimal choice

Optimal choice: max $\left\{\mathrm{NPV}_{profit}(\mathrm{a}), \mathrm{NPV}_{profit}(\mathrm{b})\right\}$

Therefore, the *NPV* of the profit of total supply chain

- **in case of local production in Italy (a)**

$$\mathrm{NPV}_{profit}(\mathrm{a}) = \mathrm{NPV}_{prod} - NPV(E) - NPV_{ord} = \sum_{i=1}^{n}\left(p_i\,(1+\delta_i)\right)\tilde{x}_i(\rho) - \frac{1}{\rho}\sum_{i=1}^{n} c_{L,i}(1+\alpha_{E,i})L_i\,\frac{e^{-(\rho)t_i(1+\sigma_i)}\hat{P}_i}{\Gamma_i+\Delta\Gamma_i} -$$

$$-\left\{\frac{\mathbf{K}}{\rho}\right\}\left[\frac{e^{-(\rho)t_1(1+\sigma_1)}\hat{P}_1}{\Gamma_1+\Delta\Gamma_1} \quad \cdots \quad \frac{e^{-(\rho)t_n(1+\sigma_n)}\hat{P}_n}{\Gamma_n+\Delta\Gamma_n}\right]^T$$

additional INVESTMENT in ergonomics

- **and in case of extension of the supply chain to foreign country (b)**

$$\mathrm{NPV}_{profit}(\mathrm{b}) = \mathrm{NPV}_{prod} - NPV(R) - NPV_{ord} - NPV_{tr} = \sum_{i=1}^{n}\left(p_i\,(1+\delta_i)\right)\tilde{x}_i(\rho) -$$

$$-\frac{1}{\rho}\sum_{i=1}^{n}\left\{\left[c_{L,i}(1+\alpha_{R,i})L_i + c'_{L,i}\,L'_i\right]\frac{e^{-(\rho)t_i(1+\sigma_i)}\hat{P}_i}{\Gamma_i+\Delta\Gamma_i}\right\} - \left\{\frac{\mathbf{K}+\mathbf{E}^T\mathbf{\Pi}}{\rho}\right\}\left[\frac{e^{-(\rho)t_1(1+\sigma_1)}\hat{P}_1}{\Gamma_1+\Delta\Gamma_1} \quad \cdots \quad \frac{e^{-(\rho)t_n(1+\sigma_n)}\hat{P}_n}{\Gamma_n+\Delta\Gamma_n}\right]^T$$

Contribution for workers early retirement

Replacement ratio

rr_{erp} = ratio between the early retirement pension and the gross salary

Actuarial present value

Contribution rate $\alpha_R(x,n,h)$ for insurance covering early retirement pension at x age of worker when entering the scheme for n years of early retirement provision and h years of contributing to the schemes

$$\alpha_R(x,n,h) = \frac{{}_h p_x \cdot v^h \cdot (1+\gamma_2) \cdot \sum_{k=0}^{n-1} {}_k p_{x+h} \cdot v^k}{(1-\gamma_1) \cdot \sum_{k=0}^{h-1} {}_k p_x \cdot v^k} \cdot \; rr$$

Replacement ratio

Probability that *x* years old will survive *h* years

Percentage of the administrative fee that insurance company charges for each payment of premium or pension benefit

Discounting factor where *o* is the annual interest rate.

Actuarial present value should be

on roads (i,j):

$$c_{L,i,j} \cdot \alpha_R(x,n,h,rr)_{i,j}\left(1-\gamma_1\right) \cdot \sum_{k=0}^{h-1} {}_k p_x \cdot \upsilon^k =$$

$$= {}_h p_x \cdot \upsilon^h \cdot \left(1+\gamma_2\right) \cdot \sum_{k=0}^{n-1} {}_k p_{x+h} \cdot \upsilon^k \cdot \quad rr_{i,j} \cdot c_{L,i,j}$$

in nodes (j):

$$c_{L,j} \cdot \alpha_R(x,n,h,rr)_j\left(1-\gamma_1\right) \cdot \sum_{k=0}^{h-1} {}_k p_x \cdot \upsilon^k =$$

$$= {}_h p_x \cdot \upsilon^h \cdot \left(1+\gamma_2\right) \cdot \sum_{k=0}^{n-1} {}_k p_{x+h} \cdot \upsilon^k \cdot \quad rr_j \cdot c_{L,j}$$

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Actuarial present value of early pension contributions - APV

$$APV_{i,j} = c_{L,i,j} \cdot \alpha_R(x,n,h,rr)_{i,j}\left(1-\gamma_1\right) \cdot \ddot{a}_{x:\overline{h}|}$$

$$\ddot{a}_{x:\overline{h}|} = \sum_{k=0}^{h-1} {}_k p_x \cdot \upsilon^k ; \qquad \alpha_R(x,n,h,rr) = A(x,n,h,rr)$$

Age at first employ.	Working period	$\ddot{a}_{x:n}$	${}_n p_x$	Retirement age	$\ddot{a}_{x-n:\overline{h}\vert}$	$A(x,n,h,rr)$	
x	n			x+n		rr=1	rr=0.6
25	40	38,83	0,91	65	4,909	0,115	0,069
25	41	39,73	0,90	66	3,941	0,089	0,054
25	42	40,62	0,89	67	2,969	0,065	0,039
25	43	41,50	0,89	68	1,989	0,042	0,025
25	44	42,38	0,88	69	1,000	0,021	0,012
25	45	43,25	0,87	70	0,000	0,000	0,000

Net present value of investiments and main-tenance of robots for depreciation period dp

$$\alpha_{E,j}(dp) = \left[(VCR / \sum_{k=0}^{dp-1} \upsilon^k) + M_C^Y \right] / L_C^Y$$

Yearly labour costs per robot

Price of robot	annual maintenance costs	annuity			annuity + maintenance			NPV of investing and holding costs of the robots	
VCR	M_C^Y	*dp=5 years*	*dp=10 years*		*dp=5 years*	*dp=10 years*		***dp=5 years***	***dp=10 years***
30,000	**1,500**	**6,599**	**3,700**		**8,099**	**5,200**		**131,986**	**74,003**
45,000	**2,250**	**9,899**	**5,550**		**12,149**	**7,800**		**197,978**	**111,004**
60,000	**3,000**	**13,199**	**7,400**		**16,199**	**10,400**		**263,971**	**148,005**

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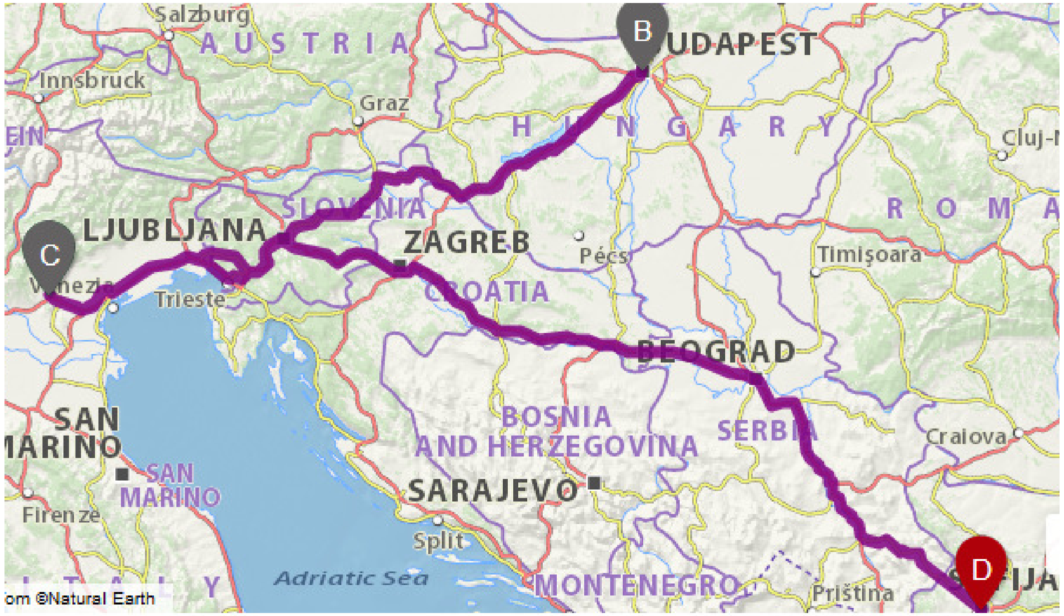
The case study



Ratio to Italian salary

[EUR]	Labour costs Hourly	Labour costs Yearly	k_{α}
Italy	20.00	38,400	1
Hungary	8.30	15,936	0.415
Bulgaria	4.40	8,448	0.22

Distance		Transport Price/km	Transport/ truck	Pcs/ load unit	Load units/ Truck	pcs/ truck	transport/ pcs
	km	EUR	EUR			EUR	EUR
Vicenza – Budapest	800	1.2	1560	80	33	2640	0.59
Vicenza – Sofia	1300	1.2	960	80	33	2640	0.36

Results of numerical example

- if we decide to remove all perturbations (in timing and quality) caused by ageing of workers, by investing in 8 collaborative robots which cost 60,000 EUR each and depreciation period is 10 years, which increase: $NPV_{prod} - NPV_{ord}$ for 20% because of timing and product quality, than (in this expression investments are not allocated to the workplaces; NPV (I)= $8 \cdot 148{,}005$ EUR) :

$$\Delta NPV_{profit}(a) = 0.2 \cdot (NPV_{prod} - NPV_{ord}) - 1{,}184{,}040 \quad EUR$$

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Results of numerical example

The NPV of keeping production in Italy is higher in comparison to the option to move production to foreign country without invest in ergonomics tools (+12% and +20% in this specific case),

while allocation of activities in the foreign countries and paying in the occupational pension funds gives:

Labour costs

Transportation costs including costs of transportation delay

$$\Delta NPV_{profit}(b, Bud) = 0.2(NPV_{prod} - NPV_{ord}) - \frac{1}{\rho}\sum_{i=1}^{n}\left[c_{L,i}(1+\alpha_{R,i}+k_{\alpha}(Bud))L_i + \sum_{j=i+1}^{n} h_{j,i}b_{j,i}\tau^{Bud}{}_{j,i}\right]\frac{e^{-(\rho)t_i}\hat{P}_i}{\Gamma_i}$$

$$\Delta NPV_{profit}(b, Sof) = 0.2(NPV_{prod} - NPV_{ord}) - \frac{1}{\rho}\sum_{i=1}^{n}\left[c_{L,i}(1+\alpha_{R,i}+k_{\alpha}(Sof))L_i + \sum_{j=i+1}^{n} h_{j,i}b_{j,i}\tau^{Sof}{}_{j,i}\right]\frac{e^{-(\rho)t_i}\hat{P}_i}{\Gamma_i}$$

Conclusion and next step

- In this specific case study, the best solution was always to invest in ergonomics and collaborative robots and keep production in Italy, if $\rho \leq 10\%$ which is always the case.

- The NPV of keeping production in Italy is higher of the option to move production foreign without invest in ergonomics tools (+12% and +20% in this specific case of $\rho = 4\%$ which is quite high today).

- The paper demonstrate that the extended MRP model could be correctly applied to evaluate the trade-off between investments in ergonomics and collaborative tools or production in foreign country, where the costs of human resources are lower.

- In future researches we will try to generalize the outcomes of this case application by making computation and testing in other industrial sectors and according to different values of the input parameters.

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Thank you very much for attention

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