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Blood vessels and human liver as bio-inspiration to reduce internal transport costs in factories.

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Abstract

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This paper presents novel bio-inspired approaches to assign operational resources (OR´s) like machines, workstations and departments within factory layouts. The resarch was done within the Project BioFacLay. First results were presented from Daniel Tinello at ICBE 2016 in Ningbo (Tinello et al. 2016). Now we found togehter with Biologists in Germany two more analogies for future factories.

First we investigated the structures and growth processes of **blood vessels** and found that these biological principles and structures help to enhance the allocation of OR´s within factory layouts. The blood vessel system is designed to minimize hydrodynamic resistance (energy for the distribution of resources). It is interesting to note that the underlying principles of a blood vessel system of a mouse are like that of a whale. West et al. write: “Thus, a whale is 10^7times heavier than a mouse but has only about 70% more branchings from aorta to capillary.” (West et al. 1997, S. 123). Nevertheless, the blood vessels of both animals grow according to the same law (see Figure 1) which in the end enables an efficient blood supply to all organs and body parts. This is equivalent to minimizing the transport distances (Brummer et al. 2017). So as can be seen in Figure 2 we rearanged a layout of an Austrian factory (1.) by applying different blood vessel laws (2. & 3.). Afterwards the layout variants where compared with key performance indicators of logistics (4.).

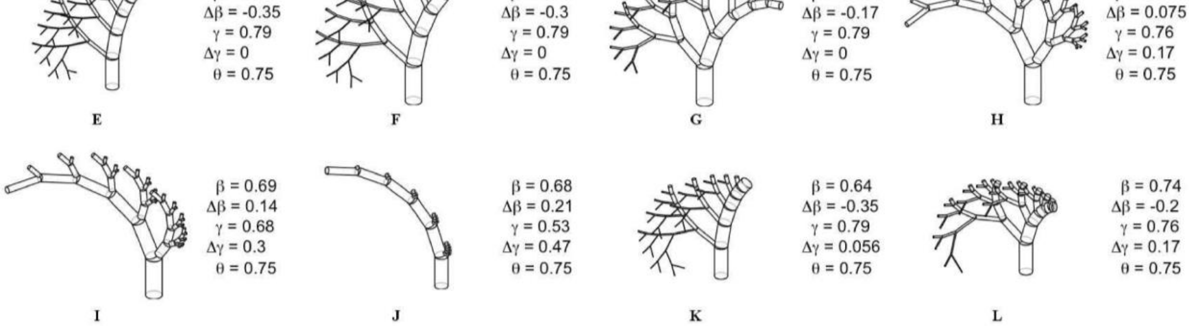
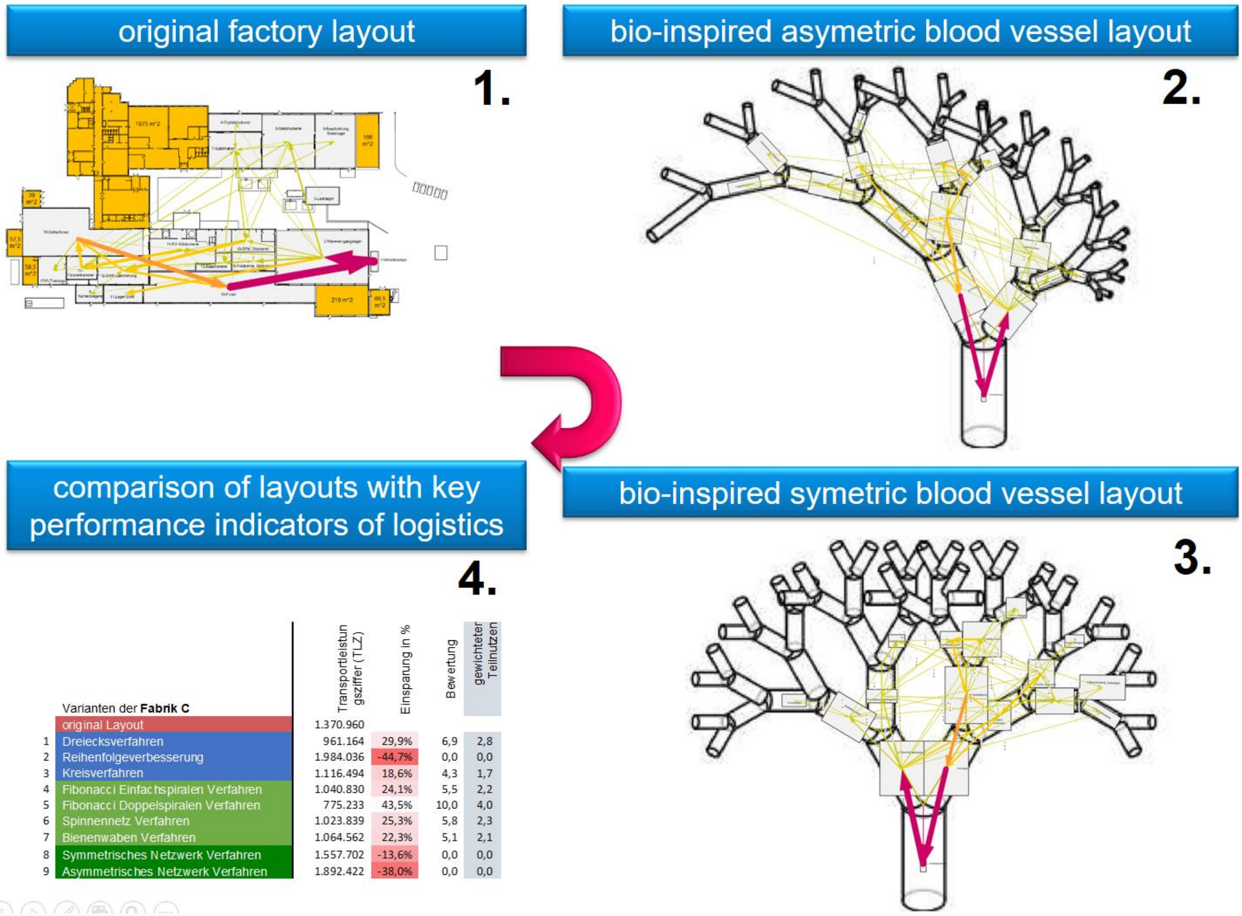


Figure 1: Laws for the growth of blood vessels ((Brummer et al. 2017), p. 6)

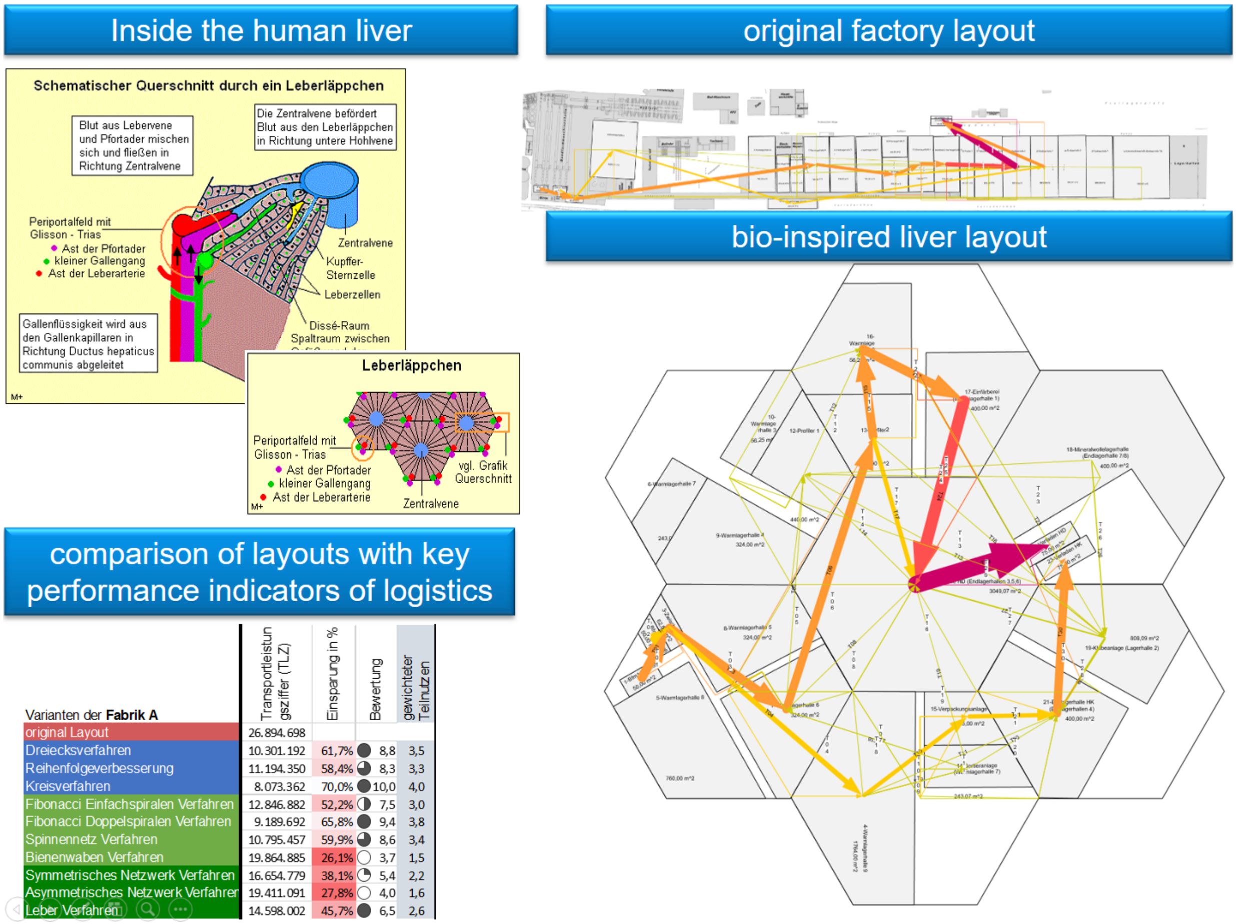


	Varianten der **Fabrik C**	Transportleistungsziffer (TLZ)	Einsparung in %	Bewertung	gewichteter Teilnutzen
	original Layout	1.370.960			
1	Dreiecksverfahren	961.164	29,9%	6,9	2,8
2	Reihenfolgeverbesserung	1.984.036	-44,7%	0,0	0,0
3	Kreisverfahren	1.116.494	18,6%	4,3	1,7
4	Fibonacci Einfachspiralen Verfahren	1.040.830	24,1%	5,5	2,2
5	Fibonacci Doppelspiralen Verfahren	775.233	43,5%	10,0	4,0
6	Spinnennetz Verfahren	1.023.839	25,3%	5,8	2,3
7	Bienenwaben Verfahren	1.064.562	22,3%	5,1	2,1
8	Symmetrisches Netzwerk Verfahren	1.557.702	-13,6%	0,0	0,0
9	Asymmetrisches Netzwerk Verfahren	1.892.422	-38,0%	0,0	0,0

*Figure 2: Bio-inspiration **one**: Blood vessel laws as model for factory layouts*

Furthermore, we investigated the structure of the **human liver**, especially the transports through the capillary network in the liver lobules, to mimic the pattern for factory layouts. The liver is the largest unpaired organ of the human organism. There's a lot of transport in the liver. The liver lobules (production unit) can be addressed as the basic units of the liver, whose centre forms a vein and is surrounded by connective tissue pathways (way system in the factory). A vein (*vena portae*) transports nutrients (delivery of raw materials), the artery (*arteria hepatica propria*) transports oxygen (energy supply) and another vein (*vena cava inferior*) transports the converted substances (outgoing goods) (Schiebler und Korf 2007). So there are quite some analogies for logistics within the liver. In Figure 3 we rearanged an austrian factory by applying thesee liver principles.

To prove the feasibility of the proposed methodology, we collected material flow data from three existing factories. We implemented the original factory layouts within our model as reference. After examining 9 different variants, we found that our bio-inspired approaches were able to keep up with traditional layouts, and in factory A, the biomimetical liver approach could even beat the key performance indicator of the original layout by 45,7%. And if the following assumption of Tompkins and White is true, then the effort to build biologically inspired factory layouts can be worthwhile in the future: "It had been estimated that between 20% to 50% of the total operating expenses within manufacturing are attributed to material handling. Effective facilities planning can reduce these costs by at least 10% to 30% and thus increase productivity." (Tompkins und White 1984, S. 5)



Varianten der **Fabrik A**	Transportleistungsziffer (TLZ)	Einsparung in %	Bewertung	gewichteter Teilnutzen
original Layout	26.894.698			
Dreiecksverfahren	10.301.192	61,7%	8,8	3,5
Reihenfolgeverbesserung	11.194.350	58,4%	8,3	3,3
Kreisverfahren	8.073.362	70,0%	10,0	4,0
Fibonacci Einfachspiralen Verfahren	12.846.882	52,2%	7,5	3,0
Fibonacci Doppelspiralen Verfahren	9.189.692	65,8%	9,4	3,8
Spinnennetz Verfahren	10.795.457	59,9%	8,6	3,4
Bienenwaben Verfahren	19.864.885	26,1%	3,7	1,5
Symmetrisches Netzwerk Verfahren	16.654.779	38,1%	5,4	2,2
Asymmetrisches Netzwerk Verfahren	19.411.091	27,8%	4,0	1,6
Leber Verfahren	14.598.002	45,7%	6,5	2,6

*Figure 3: Bio-inspiration **two**: human liver as model for factory layouts*

Literature

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