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CRITICAL ANALYSIS OF PLYWOOD PRODUCTION SYSTEM MODEL

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ABSTRACT
The article attempts to analyze the process of plywood production of a Polish plywood manufacturer. The aim is to describe the possibility of change in the production process in order to optimize production and minimize waste. It also indicates the possibility of minimizing production costs. Costs reduction could be achieved by modernization of technology and production equipment, as well as through the optimization of human resources management. However, in case of each particular change, the specificity of the whole industry and individual plant must be taken into consideration.

KEYWORDS
management, organization, plywood, production, waste.

Introduction

Manufacture of wood products in Poland compared to other EU members is significant, and the key products in the field are wood-based panels [COM 474 2005]. For example, in Poland, in 2010, about 6.5 million m^3 of wood-based panels was produced, which accounted for 12% of the market share of all EU members and to this day, our country ranks second (after Germany) in Europe. Not without importance is trade exchange of Polish wood sector with other states [http://faostat.fao.org]. Competitiveness of Polish companies lies in the high technical level (modern and efficient technological lines) and the highly skilled workforce, which is directly reflected in the quality of final products.

Wood-based panel plants are a part of dynamic growing wood industry. In Poland there are several modern plywood and other wood-sandwich products manufacturing plants. The research conducted on innovation development of the companies indicates the potential for the deployment of new solutions. Such innovations are often of technological nature [1–3]. Nevertheless, they have to be adapted to the needs of both customers and the competitive situation on the market.

The aim of this study is to describe the activities of a typical plywood factory characterizing its production system model according to [4] (Fig. 1). The model will be critically analyzed in terms of:
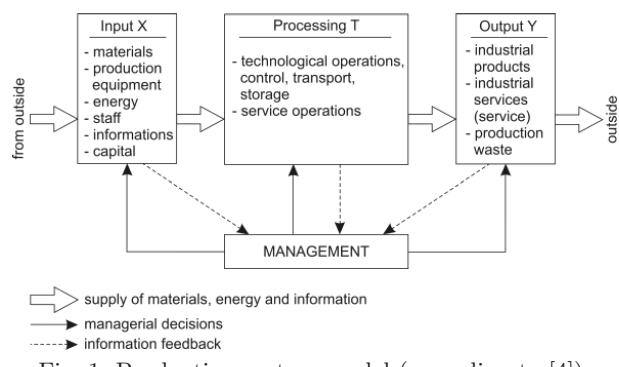

Fig. 1. Production system model (according to [4]).

1. significance of its elements in described factory;
2. discovery of new opportunities in both the technological and organizational sphere, that have the potential to extend the range of products, thus achieving competitive advantage;
3. implementation of the method of sustainable development based on the use of natural resources, which is particularly important in this sector.

Types of production models

In manufacturing plants the right planning of raw materials necessary to ensure production continuity plays a key part. The supply of raw material for plywood plants may be realized in two alternative ways: by storing the raw material in the long term (greater parts on the storage place) or buying it in batches for the current production. A method allowing for raw material demand coordination is material requirements planning (MRP). The method uses master plan of the production in order to plan the supply of raw materials. Extension of master production schedule enables the company to plan deliveries of raw materials at the precise moment when they are needed. According to [5] material requirements planning (MRP) is a computational technique used for the push paradigm that converts the master production schedule (MPS) into a detailed schedule for raw materials and components used in the end products. Parts are loaded into the AMSs based on minimizing the difference between the actual products and the scheduled orders released.

Another example of a production organization can be the properly planned logistics process. It allows for both proper planning of the raw material needed for manufacture as well as waste management system and transport policy.

In the paper, [6] it has been presented which elements a production system may consist of (Fig.2).

A model that takes into account all management aspects (resources, materials and logistics), thus allowing for the modification and search of savings is the production system model, which incorporates the technological and economic aspects (Fig. 2). The main task of strategic distribution logistics management is to produce competitive tools to support the company's competitive strategy [7].

In this paper the analysis will be conducted on a representative example of a wood processing company (plywood producer), for which the authors have identified main elements of the production system (Fig. 3).

Fig. 2. Elements of the operational logistic action system [6].

Fig. 3. Main elements of the production system in the analyzed plant (own work).

According to [8] in management process, it is possible to identify the following elements:

1. Leadership. The company's leadership system, values, expectations, and public responsibilities.

2. Information and analysis. The effectiveness of information collection and analysis to support customer-driven performance.

3. Strategic planning. The effectiveness of strategic and business planning and plans deployment, with a strong focus on customer and operational performance requirements.

4. Human resources focus. The success of efforts to realize the full potential of the workforce to create a high performance organization.

5. Process management. The effectiveness of systems and processes for assuring the quality of products and services.

6. Business results. Performance results, trends and comparison to competitors in key business areas-customer satisfaction, financial and marketplace, human resources, supplier, partners and operations.

7. Customer and market focus. How the company determines customer and market requirements and expectations, enhances relationships with customers and determines their satisfaction.

In the analyzed example, the plant buys wood raw materials and other materials directly connected with production (resins, hardeners, fillers etc.), as well as water, electricity, fuel, consumables (oil, lubricants) and cleaning agents etc.

The elements of input vector, affecting the realization of production assumptions are:
- plant capital,
- access to wide information,
- access to raw materials needed for production,
- the employees.

Plant capital comprises fixed assets (buildings, means of transport) and current assets. The share of managing and administration staff in all employees is around 15%.

Every organization builds its activity on gathering information essential to compete on the market. In order to realize the core business the analyzed company is trying to obtain information concerning the following:
- prices and quality of the competitors' products,
- new markets, including the demand for new types of products,
- possibilities of new technologies purchase,
- acquisition of skilled workers and qualifications improvement of those already employed,
- access to new suppliers.

Collected information allows for carrying out research on the plant development in the area of new technologies, waste management policies or distribution. The aim of the described model is to show possible changes that may arise when applying modifications in one or more selected areas of the plant.

The analyzed situation of plywood manufacturing process begins with the purchase of raw material in the form of logs or block. The raw material is stored in landfill yards. Manipulation of raw material (splitting the logs in length corresponding to the production profile) is done using transverse circular saws. The prepared raw material is subjected to peeling operation. Stripped material is processed hydrothermally. The plasticized material is processed on peeling machines to produce veneers. The acquired veneer' ribbon is divided with the simultaneous elimination of defects in full or incomplete sheets, which are then dried in a drying-through chambers. Undersized sheets are bonded and re-distributed to all forms. At the same time a qualitative classification of veneers is conducted, divided into two groups: veneer for the outer and core layers. Veneers prepared in accordance with established production are assem-

bled in sets. The adhesive mass is applied by roller only on every second sheet. The completed sets are pre-pressed in the single-shelf cold press, and next, in the multi-shelf hot press with automatic loading and unloading. The produced plywood is conditioned prior to sizing and grinding. The final stage of production process is quality control. The plywood of poorer quality, which could be improved, is repaired. Finished plywood is stored in a warehouse or transferred for further processing.

The most important issue in the production of plywood is the policy of the company supplying the raw material (wood), obtained mainly from the supplier which is the National Forests (95%). The other sources are private forests and import. Price of final products (plywood) is strongly dependent on timber prices. Another important aspect influencing the final product is finding suppliers of other materials for the production, which not only offer low prices, but also meet high quality and ecology standards. The result is, among other things, reducing the need for disposal, thereby reducing costs and finding new markets and potential customers for the final product.

Compared to other wood-based material companies (particleboard, MDF), plywood industry is characterized by poor automation level. Because of that, it is important that workers should have experience in the range of wood processing.

Due to the opening of the electricity supply market, signing more profitable contracts became possible. On the other hand, the prices of other media (coal, oil, gas), purchased by the plant, are unstable with a tendency to increase.

Plywood plants are very flexible in its approach to customer needs. This entails the possibility of producing short runs of products, according to individual orders.

In the plywood industry, there is also information flow relating to changes in technological processes with a view to optimizing them. The exchange of such information is at trade fairs, conferences, through professional journals, associations, and through collaboration with research institutions of the wood sector.

The observation of Polish plywood industry shows that the significant majority of plants use the same input vector factors. Differences in their activities, which are based on the proportions of the final and secondary products, have their origins in the processing phase. The next stage of this work is to analyze the potential modification of selected steps of the plywood production. This will show the optimization of plywood production, based on modifications of the initial stage – veneer manufacturing. Table 1 and Table 2 show the possible options.

Table 1
Present operations of veneer production (own research).

Operation	Actually applied	Disadvantage	Advantage
Raw material' store	Store in a landfill yards	Pre-drying, spraying necessity, significantly large surface	Easy access when manipulate
Manipulation	Transversal saw blade	Limited diameter of the processed log	Limited manual labor
Debarking	Before hydro-thermal processing	In case of some wood species the cracks occur	Hydrothermal processing shortening, no pools' contamination, no wood discoloration
Hydro-thermal processing	Boiling	Water consumption, necessity to clearing and replacing	Soft plastification process, easy to control
Peeling	Spindle peeling machine	Worse use of raw material	Less complicated construction
Raw material' store	Store in a landfill yards	Pre-drying, spraying necessity, significantly large surface	Easy access when manipulate

Table 2
Potential operations of veneer production (own research).

Operation	Potential	Disadvantage	Advantage
Raw material' store	Water or water-landfill yards	Necessity to remove from water for Winter, access to the water reservoir, complicated manipulation	Better quality of raw material, the possibility of long-time store without quality decrease, simple infrastructure
Manipulation	Chainsaw	Manual service, process conducted directly on the yard	Flexibility
Debarking	After hydro-thermal processing	Hydrothermal processing elongation, pools' contamination, wood discoloration, elongation of the time from the hydrothermal processing to pilling	Easier debarking and smaller damage of the valuable wood zone, longer work time of the debarking machines
Hydro-thermal processing	Brewing or brewing with the water pad	Intensive process, hard to control, complicated equipment	Possible to realize in chambers, lower amount of sewages
Peeling	Spindleless peeling machine	More complicated construction and use, high cost effectiveness	Better use of raw material, higher efficiency
Raw material' store	Water or water-landfill yards	Necessity to remove from water for Winter, access to the water reservoir, complicated manipulation	Better quality of raw material, the possibility of long-time store without quality decrease, simple infrastructure

In the first step, which contains storage of raw material, it is possible to use water or water-landfill yards. Despite the disadvantages connected with the need to remove the raw material from water in winter, access to the shoreline of water body and complicated manipulation, the raw material stored in this way is of high quality and there is a possibility of long-term storage without quality decrease. This type of storage opens the possibility of flexible management of raw material supply.

Currently used material handling operation, which entails its division with the use of a transverse saw blade, seems optimal. The limited human input factor is an advantage. At the step of manipulation, the preliminary sorting of raw materials occurs. The alternative can be manipulated directly on the yard of the raw material using mobile chain saws. This enables a more favorable manipulation while sorting. This avoids the intermediate storage of the raw material with current demand, which simplifies the step of the manufacturing process.

At the next step, before hydrothermal treatment, raw material is subjected to debarking. Debarking after the hydrothermal treatment is carried out with less effort, and the results of the operation are more satisfying. However, most of the factories prefer debarking prior to hydrothermal treatment. It has been shown that such a sequence reduces processing time, pools' pollution and the color changes in wood are subtler and less frequent. The above-mentioned hydrothermal treatment is carried out in hot water. This process can be realized under mild conditions, which provides high quality of the material. The main disadvantage of that solution is the need for water purification. An alternative for hot water treatment is steaming. It leads to time savings, but the

main problem might be reduced quality of the product, difficult process control and insufficient plasticizing of wood. The advantage of steaming is a limited amount of generated waste and the option for the process to be performed in chambers, so that boiling pits are not necessary. Veneers are subjected to rotary cutting. An alternation in this operation is using a new type of peeling machine, which primarily increases material efficiency and improves the quality of the obtained veneers. This solution is characterized by a higher degree of complexity of the machine.

The end of the production cycle of the company will generate the following output:

- finished goods from basic production in the form of plywood and its products,
- side production: elements of fencing, wood chips, firewood, heat, waste,
- capital plus profit from the sales of finished goods and side production,
- waste (sizing, non-wood materials, contaminated water, container, used lubricants and oils, municipal),
- information (technical costs of the production, customer feedback, cost information).

The company selected for the analysis, over the last few years, has made many changes and upgrades allowing for a broad consideration of all aspects of the production system model. The modern lines allow for a better use of raw materials while reducing waste and expanding the number of varieties of finished products. Attention should also be paid to the output vector which, thanks to modern technology, reduces the amount of waste such as sizing and have a positive effect on the cost policy of the company.

However, most of the plywood plants operating on the Polish market are characterized by older technology that is not enough to achieve both greater efficiency and effectiveness. Obsolete machine parks also cause increases in waste suitable only for fuel and not for further treatment and sales. An important aspect of the production system model that distinguishes technologically weaker plants is the increased total production cost. Its growth will be largely affected by the use of employees – not modern machinery and equipment.

In the model, in addition to elements of vector input and output, management plays a key role. Depending on the nature of production, it may cover different areas. The plywood plant has been identified in the following management features:

- trading of raw materials,
- purchase of additional materials,

- research and development (in plants with poor automation level, research and development is conducted on a limited basis due to lack of both – the means to conduct the research and the possibility of future implementation),
- distribution,
- marketing,
- financial management,
- quality, human resources and sustainable development policy.

Also in this case, you may notice great differences between plants with modern production lines and those using the old production system. The personnel policy, the same expenditure on staff development and training will be reduced in automated factories, due to reduced employment. Such companies usually increase the costs associated with the quality policy in order to attract as many customers as possible.

These steps are part of a typical management model which manufacturing companies use. Divided powers often lead to inconsistencies in the plant policy, which could translate into risks associated with inadequacy of demand for materials needed for production or incoherent policy, distribution and marketing of finished products.

Therefore, it is worth paying attention to the new approach to management, which is the policy of sustainable development that is adapting such management of natural resources as to meet the social needs of both current and future generations, harmoniously combining the care of cultural heritage, combined with the progress of civilization and different economic groups. The use of the cited strategy helps to improve competitive position, the image in the eyes of potential customers and to reduce environmental conflicts.

Partial use of such management strategies can be seen in the described wood industry plants.

An important aspect contributing to changes in the enterprise is the role of post-production waste. The possibility of waste recycling will reduce the cost of disposal, resulting in its development as an alternative fuel used for technological purposes. Introduction of effective water recirculation system used for irrigation of wood in the landfill gas will contribute to costs reduction.

New technologies allow for positive changes in the companies in a broad aspect of their business. But we must not forget that not all businesses can afford such a solution, because of the high cost of innovation. Thus, the lack of innovation policy will act as a barrier to new, more demanding markets entry.

Conclusion

Summing up the above considerations, there is a positive trend regarding changes in the investment management in plywood industry. The greatest changes can be seen in the modernization of production lines, which are designed to improve the efficiency of the production process in terms of productivity, quality and prices of finished products. It should also be pointed out that the introduction of the proposed changes directly translates into reduction of emissions of environmentally harmful factors (dust, noise, emissions of volatile organic compounds). Conducted environmental policies will improve the output vector, resulting in reduction of the elements that compose it.

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A CONCEPTUAL ANALYSIS OF COGNITIVE DISTRACTION FOR TRANSIT BUS DRIVERS

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ABSTRACT
The purpose of this paper is to analyze cognitive distraction data to determine its impact of transit bus drivers' capability. Much of the theory and results applied in this paper are from the work of researchers working on similar projects. In order to understand cognitive distraction and how it can be mitigated, a Cognitive Distraction Model is outlined. The model was analyzed to evaluate the correlation between driver capability, and demographics and driving patterns. A model that provides an understanding about cognitive workload and driver capability could provide better psychological solutions to mitigate the number of accidents due to cognitive distraction and develop relevant driver training programs. Through additional research from the neurological and behavioral sciences, regulators could develop a better understanding of the causal factors and ways to control cognitive distraction.

KEYWORDS
Accident Risk Management, Driver Inattention, Driver Distraction, Physical Distraction, Mental Distraction, Driver Training, Cognitive Distraction, Multitasking, Behavioral Science.

Introduction

According to the National Highway Traffic Safety Administration (NHTSA), distracted driving claimed over 5,000 lives and nearly half a million injuries across the U.S [1]. The analysis of accident databases shows driver distraction to be a significant cause of accidents on the highways [2]. This growth in transit bus services coupled with proliferation of advanced in-vehicle technologies are causing more distractions. *Distraction occurs when a driver's attention is diverted away from driving by a secondary task that occurs approximately 30% of the vehicle movement time [3]*. Government regulators have proposed policies such as the recent National Transportation Safety Board's (NTSB) recommendation ban all cell phone usage including hand-free devices while driving, except in emergency situations [4]. The hand-free devices have been included in the ban, since although they eliminate visual and physical distraction, their usage results in cognitive distraction [5].

Various studies have shown that visual and physical distractions are a major cause for automobile accidents mainly because such studies are easier to conduct as compared to cognitive distraction. There is a paucity of research reported in the literature [6] on cognitive-related distraction because identifying a way to properly obtain and analyze the data appears to be difficult. In an earlier study by D'Souza and Maheshwari [7], data collected on the driver's perception of each distracting activity revealed that cognitive distraction generally due to multitasking driving tasks with secondary tasks was perceived by drivers as the highest form of distraction. A more detail analysis of the relationship between the cognitive

workload and driver capability and corresponding responses is necessary for a complete understanding of distracted driving.

This paper explores the problems of distracted driving from a behavioral point of view with an attempt to formulate a concept for investigating the role a driver's cognitive state plays on their driving effectiveness. In order to understand cognitive distraction and how it can be controlled is the development and analysis of a Cognitive Distraction Model (CDM) that describes the different components of the cognitive distraction processes. A cognitive distraction model is proposed consisting of four components: Driving Tasks, Distracting Activities, Cognitive Workload, and Driver Capability. The model analyzes the drivers' response to cognitive workload and driver capability due to multitasking of driving and distracting activities. It is one of only a few studies to examine the full range of distractions and associated risk due to cognitive factors. The reason for undertaking this research was to get a better understanding of distracting activities originating in the mind since most published research on distracted driving focus on physical and visual distractions.

Research results [3, 5, 8, 9] on multitasking limitations of the brain are utilized in this paper to develop the CDM. By understanding the correlation between cognitive distraction and location, driving pattern, and driver demographics better psychological solutions can be put into place to mitigate the number of accidents due to cognitive distraction. The results anticipated from this research will provide a better understanding about cognitive distractions and how they can be avoided.

Literature review

Driver distraction represents a significant problem in the personal and public transport sector, and has been studied by several researchers [6]. The analysis of accident databases in the City of Perth, Western Australia found driver distraction to be responsible for 13.6% of all crashes on the highways [2]. A study funded by the AAA Foundation [10] identified the major sources of distraction for personal vehicles contributing to crashes, developed taxonomy of driver distractions for the U.S. driving population, and examined the potential consequences of these distractions on driving performance. The source of bus driver distractions at a major Australian public transport company was investigated using ergonomics methods through which, a taxonomy of the sources of bus driver distraction was developed, along

with countermeasures to remove/mitigate their effects on driver performance [11].

Research on cognitive distraction is limited [5, 12]. Harbluk and Eizenman [5] conducted a study on 21 drivers under conditions of cognitive distraction caused by the usage of hand-free and speech recognition devices and reported changes in driver visual behavior, vehicle control, and *subjective assessment of workload, safety, and distraction*. Multi-tasking and using a cell phone with hand-free and speech recognition devices may eliminate visual and physical distraction but cognitive distraction is still prevalent.

Transit bus drivers are required to perform multiple tasks in addition to driving such as attending to passengers in addition to their primary activity of driving by multitasking. A white paper by the National Safety Council states that *multitasking is a myth* since the human brain can only perform one task at a time sequentially and cannot perform multiple tasks simultaneously [8] although, some researchers [13] have concluded that drivers can meet specific performance criteria by controlled multitasking. The accident reports filed by law enforcement officials rarely document cognitive distraction as the cause of accidents. Such accidents are possibly recorded in Virginia Traffic Crash Facts under the category of *No Violation* [14]. Yang [15] analyzed trends in transit bus accidents and related factors such as road design, weather, lighting condition, etc, recorded by the National Transit Database (NTD), but no analysis was reported on cognitive driver distraction. Driver cognitive status is normally not known for a large number of accidents but it is estimated that 10.5 % of drivers were distracted at the time of the accident [3]. Due to lack of reporting cognitive distractions by drivers, the associated risks and impact on performance is difficult to study and hence, not been well-understood.

Factors such as location, driving hours/week; and driver age, gender, and experience have an impact on public bus driver distraction [16]. A driving route running through a densely populated area servicing a greater number of passengers accompanied by higher external sources of distraction due to more frequent stops and more other road users or pedestrians [10]. A driver less familiar with the driving routes is more likely to be involved in rear-end accidents at signalized intersections [17]. Studies on the impact of age, gender, driving experience, and driving demands on driving performance suggests that younger (below 25 years) and older (above 70 years) drivers tend to be more vulnerable to the effects of distraction than middle-aged drivers [1, 18]. Older female drivers had increased risk of crash due to poor attention, cogni-

tive, executive, and motor skills [18]. The age group > 75 years presented the highest risk due to age-related problems with physical and cognitive abilities [18]. Blower et al. [19] reported that age, sex, hours driving, trip type, method of compensation, and previous driving records are related to driver errors. The impact of age and cognitive functions on driving performance has been studied extensively to predict cognitive distraction with a computational cognitive model and validating the results through simulation [20]. O'Connors [6] has proposed a relationship between odds ratio and complexity of secondary tasks where the computed odds ratios were 3.1 for complex secondary tasks, 2.1 for moderate secondary tasks, and 1.0 for simple secondary tasks. From the odds ratio, O'Connors [6] has computed the risk of involvement in a crash or near crash

Researchers have discussed driver's cognitive interaction while driving to understand the occurrence of accidents. Wong and Huang, [12] have proposed a research framework for studying driver's mental process in order to determine how accidents occur which includes a conceptual framework of driving mental process that is a step towards development of a workable model to study accident causality. Trick et al. [21] have provided a conceptual framework that combines the two fundamental dimensions of attention selection in order to have a more comprehensive driving theory. Although the work of Wong and Huang [12] and Trick et al. [21] are not directly related to driver distraction, their framework provides useful inputs for development of the cognitive distraction model in this paper.

Analysis of cognitive driver distractions

A self-administered survey was used to collect drivers' current perception of cognitive distraction. The region covered by the transit agency was divided into two locations: the Northside and Southside due to the difference in population density, street layouts, and accident rates. The Southside is more commercialized and densely populated with a higher accident rate of 62 accidents/million miles compared to the Northside's rate of 54 accidents/million miles.

Potential Sources and Duration of Distraction

The transit bus drivers rated how distracting they found listed activities and the approximate duration they experienced these activities in a typical eight-hour shift. The ratings and durations for each activity was averaged and ranked from highest to low-

est [22]. The top five distracting activities shown in Table 1 are mostly passenger-related.

Table 1
Top Five Distracting Rating Activities.

Rank	Activity	Average Distraction Rating	Related Category
1	Passengers using a mobile phone	2.48	Passenger
2	Passengers not following etiquette (eating, drinking, smoking, noisy)	2.35	Passenger
3	Passengers trying to talk to you	2.23	Passenger
4	Fatigue/Sickness	2.1	Personal
5	Passengers	2.08	Passenger

The survey collected the time drivers spend per shift on various distracting activities while driving a bus. The average time for each activity was computed and sorted from highest to lowest average times. The top five activities are listed in Table 2. The bus drivers reported that much of their distracted time was on passenger-related activities.

Table 2
Top Five Distracting Duration Activities.

Rank	Activity	Average Distraction Duration (Hrs)	Related Category
1	Passengers using a mobile phone	2.66	Passenger
2	Other Road Users	2.24	External
3	Passengers	2.23	Passenger
4	Passengers trying to talk to you	1.96	Passenger
5	Passengers not following etiquette (eating, drinking, smoking, noisy)	1.84	Passenger

Driver Perception of Impact of Distracting Activities

The U.S. DOT [23] has categorized distractions as Visual, Manual, and Cognitive and reported that the severity of distractions increases as it involves more than one category. In an earlier study by D'Souza and Maheshwari [7], a driver distraction survey collected information on the three categories of distraction: visual, physical and cognitive. Around 90% of the distracting activities were perceived by the drivers as caused by Mind/Attention off the Road (cognitive). The activities were sorted by number of drivers and the top five for each category of ef-

fects are summarized in Table 3. Around 80% of the top five distracting activities were passenger-related which are caused by cognitive distraction. An Australian study [2] found that distracting activities that contributed most to a crash were conversing with passengers (11.3%), lack of concentration (10.8%) and outside factors (8.9%) [2]. Table 4 shows that cognitive distraction has the highest mean, median and mode values.

Classification of High Risk Distracting Activities

Although subjective approaches are applied for classification of distracting activities [24], this study developed an objective approach using an index. The Distraction Risk Index (DRI) estimates the potential risk associated with each Risk Zone activity. The DRI for the seven Risk Zones I, II, and III activities are shown in Table 5.

Table 3
Top Five Ranking of Distraction Categories as Perceived by Driver.

Activity	Distraction Category	Visual Effects of Distraction	Physical Effects of Distraction	Cognitive Effects of Distraction
Passengers using a mobile phone	Passenger	–		1
Reading (eg Route Sheet)	Operational	1	–	–
Ticket Machine	Technology	2	3	–
Climate Control	Technology	3	4	–
Passengers	Passenger	4	–	3
Disabled Passengers	Passenger	5	5	5
Fatigue/Sickness	Personal	–	1	–
Pedestrians	Infrastructure	–	2	–
Passengers not following etiquette (eating, drinking, smoking, noisy)	Passenger	–	–	5
Passengers trying to talk to driver	Passenger	–		2
General Broadcast	Operational	–	–	4

Table 4
Statistical Comparison of Driver Perception of Distraction.

Parameters	Visual	Physical	Cognitive
Mean	7.21	4.79	22.11
Median	6	5	21
Mode	4	7	21
Std. Dev.	4.84	2.37	6.39
Minimum	1	1	9
Maximum	19	18.11	33
Range	18	10	24

Table 5
Distraction Risk Index.

	Passenger using mobile phone	Passenger talk to driver	Fatigue/sick	Passengers	Ticket machine	Non-etiquette passenger	Climate control
Rating	90	90	90	70	50	90	50
Duration	90	70	50	70	50	50	30
Visual	30	30	30	50	70	30	50
Manual	30	30	90	30	50	30	50
Cognitive	90	90	50	70	50	70	50
Risk index	66%	62%	62%	58%	54%	54%	46%
Risk zone	I	I	II	II	III	III	III
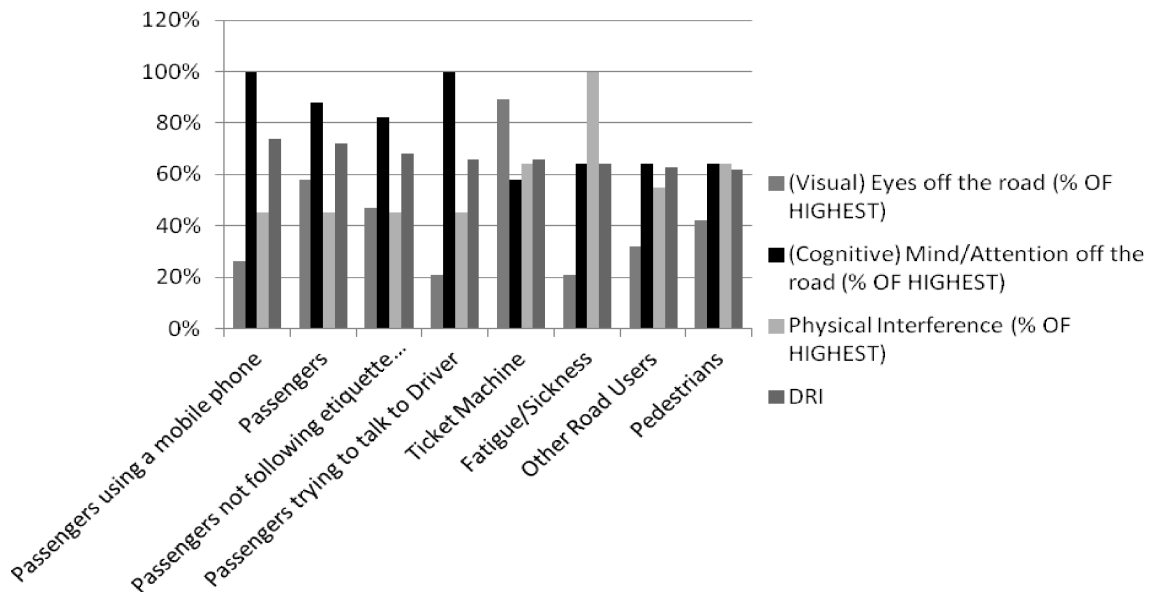
Fig. 1. Comparison of Cognitive with Physical and Visual for High Risk Distracting Activities.

Figure 1 shows the comparison of cognitive distraction with physical and visual distractions for the high risk distracting activities classified in Zones I, II, and III. Cognitive distraction is higher for most passenger-related distracting activities. Ranney [3] also identified conversation with passengers as the most common secondary task compared to eating, smoking, manipulating controls, reaching inside the vehicle, and cell phone use.

Cognitive distraction model results

An analysis of historical bus accident data for the past three years (2008–2011) was conducted at a regional transit agency to identify causes of accidents (Table 6). The monthly accidents are classified as being either *preventable* or *non-preventable*. A more detail analysis of incidents within the agency property and off-property could determine whether

it was driver distraction, driver inattention, or day time/weather conditions that played a role in the accident.

Cognitive Distraction Model

Numerous factors interact with one another when a driver is on the road, creating driver distraction. Research has clearly shown that driver distraction is largely a cognitive function and it diverts a driver's attention away from the road, producing a threat to safety. The Cognitive Distraction Model [CDM] shown in Fig. 2 comprises of four processes that contribute to driver distraction and influence driver performance. These four processes are: Driving Tasks, Distraction Activities, Cognitive Workload, and Driver Capability. These four processes interact, and they are influenced by factors such as age, driving experience, location of routes, and gender.

Table 6
Bus Accident Data (2008–2011).

Location of accident	Non-preventable	Driver distraction	Other preventable	Total
Northside	553	105	110	768
Southside	1124	227	318	1669
Total	1677	332	428	2437
% of total accidents	68%	14%	18%	100%
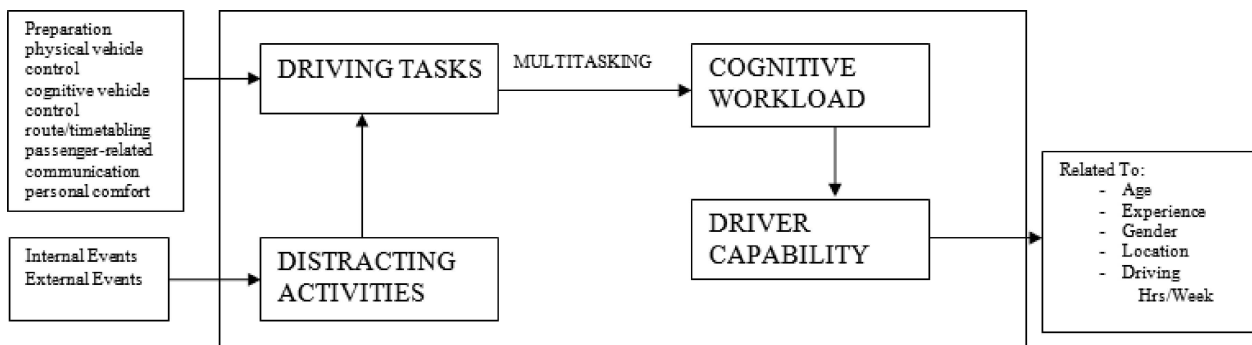
Fig. 2. Cognitive Distraction Model (CDM).

Driving Task

Driving tasks can be defined as everything that is needed to operate the transit vehicle. These driving tasks are divided into primary driving tasks and secondary driving tasks. Common examples of primary driving tasks for a transit driver are steering, using the accelerator, applying the brakes, changing lanes, determining what speed to use, and communicating to other drivers by using the turn signal and turning on the headlights. Salmon et al. [25] has presented a Hierarchical Task Analysis (HTA) which list seven categories of tasks a bus driver needs to perform while driving the bus: preparation tasks, physical vehicle control tasks, cognitive vehicle control tasks, route/timetabling tasks, passenger-related tasks, communication tasks, and personal comfort tasks.

In contract, secondary driving tasks are non-driving activities occurring approximately 30 percent (%) of moving time causing driver distraction [3]. The types of non-driving distractions reported by Wong and Huang [12] include *in-vehicle distraction, external distraction, and the acquisition of information.* Secondary driving tasks conducted internally generally include conversing with passengers, tending to passengers with infants, collecting tickets, making announcements, using a navigation system or other wireless device and managing climate control. The transit drivers are also distracted by external events such as other road users, pedestrians, weather conditions, etc. When transit drivers focus their attention on secondary driving tasks, their attention is diverted from the primary driving tasks causing distractions.

Distracting Activities

Transit drivers are confronted by numerous distracting activities as they go through their daily occupational routine. Some of these distracting activities come from external events to include navigating through road construction and flashing digital

road signs indicating which route to take. Other distracting activities relate to internal events including things associated with the driver, such as daydreaming, fatigue or illness, or hunger. Internal events within the transit vehicle also present distractions for the driver, to include conversations with the passengers, passengers using mobile cell phones, and passenger distractions due to conversations with other passengers. The culmination of these events results in cognitive overload. The driver can only focus on one thing at a time. Research has demonstrated that *multitasking is a myth* [8] and that driver's attention can only be directed to one activity at a time. Therefore, even the use of voice-operated and hands-free devices represents distractions that can present a safety hazard to the driver and passengers.

Distracted drivers experience inattention blindness. They are looking out the windshield, but do not process everything in the roadway environment necessary to effectively monitor their surroundings, seek and identify potential hazards, and to respond to unexpected situations The danger of inattention blindness is that when a driver fails to notice events in the driving environment, either at all or too late, it's impossible to execute a safe response such as a steering maneuver or braking to avoid a crash [9].

Cognitive Workload

Cognitive workload refers to the amount of information that a transit driver must process while driving. The brain controls visual, manual and cognitive driving functions as shown in functional magnetic resonance imaging (fMRI) [8]. A Carnegie Mellon University study produced fMRI pictures of the brain during a simulator run shows that cognitive distraction decreased activity by 37 percent in the brain's parietal lobe which controls driving providing a biological reason for driving risks [8]. To complicate the situation, the transit driver must use their cognitive capabilities to not only concentrate on primary

and secondary driving tasks, but to focus on routes and abide by agency regulations pertaining to issues like vehicle speed and required amount of time to get from point of departure to the scheduled destination. Dealing with passenger issues adds to the cognitive workload. Research has shown that when talking on a mobile phone, drivers tend to slow down, which demonstrates their distractedness. Cognitive workload varies according to additional factors including amount of traffic on the road, day of the week and time of day (Figs. 3 and 4). The number of accidents gradually rise between Monday and Friday and then decreases.
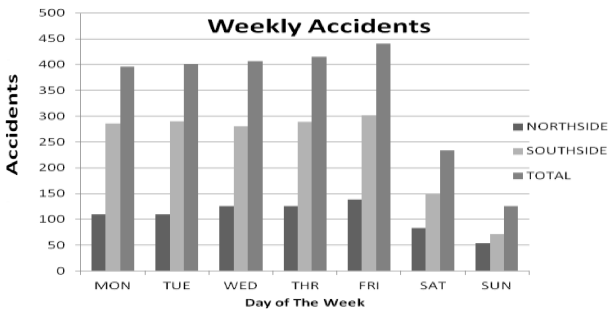
Fig. 3. Accidents on Days of the Week.
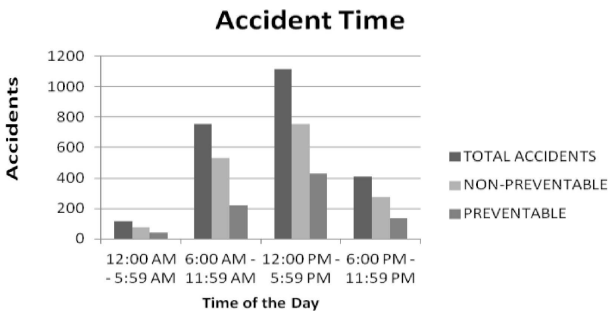
Fig. 4. Accident Time of the Day.

Distracting activities such as carrying on a conversation with a passenger or listening to a passenger's mobile cell phone conversation leads to multitasking while driving. The transit driver attempts to distribute his or her attention to both the secondary driving tasks as well as the primary tasks associated with operating the vehicle. Mental inattention begins to take place, particularly as additional secondary driving tasks are factored in. This mental inattention increases the amount of time that it takes for the driver to fully process information that being taken in and to formulate and act upon decisions made, based on such information. A threshold is reached, particularly as additional tasks are added, due to limited mental capacity, thereby strengthening mental inattention due to being overtaxed by a heavy mental workload. At this point, it becomes

impossible to multitask and the mental inattention towards the primary driving tasks produces a major crash risk.

Humans have limited mental load capability which often leads to brain "bottleneck" in which the brain is straining to secure resources for non-driving (distracting) activities which competes with the primary driving tasks. Driving experience plays a role in driving performance (Fig. 5). Experienced drivers perform common driving tasks without thinking (for example slowing down before making a turn) thus thinking that they have the cognitive capability under all driving conditions until an accident shows otherwise. When the brain's limits are stretched and information processing slows down reducing the driver's reaction time, thus increasing the risk of an accident. Figure 5 reveals that novice drivers have a higher accident rate than the more experienced drivers. Since, novice drivers are generally young, it is clear that young, inexperienced drivers are at increased risk to themselves and are also a major hazard for other road users.
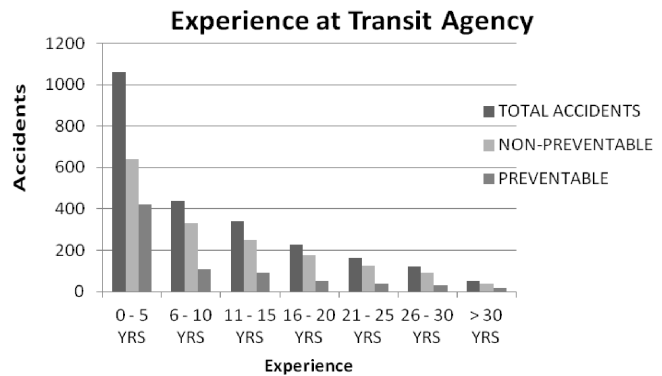
Fig. 5. Impact of Driving Experience.

There are factors that play a mediating role on driver distraction, and performance to include driver capability, number of passengers in the vehicle, and driver's age.

Cognitive distractions exist. For example, research has shown that older drivers tend to have more vehicle accidents when entering intersections [26]. In this study, passengers, passengers talking with driver, and passengers using mobile phone devices were the most prevalent reported cognitive distractions. McEvoy [2] and Ranney [3] have also reported conversation with passengers as the most common form of distraction.

Driver Capability

Driver capability depends to a great extent on the level of multitasking the driver can perform while

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executing the primary driving tasks and the secondary tasks. The brain must do attention switching", when it deals with multitasking [9]. When a driver is driving and attempts to perform a secondary task such as talking to a passenger, the brain shifts its focus and the driver develop "inattention blindness" [9] which may lead to running a red signal and a crash.

According to National Safety Council [9] multitasking impairs performance since the brain has capacity limits. According to brain researchers, "reaction-time switching costs", is a time the brain takes to switch its attention and focus from one task to another [9]. Hence, driver capability is affected which slows the reaction time to potential hazards supporting the major reason for an accident. Although the switching time is very small, repeatedly switching adds up the time.

Figure 6 shows the location of accidents and the type of accident. The non-preventable accidents are not caused by the bus driver. For example, the bus maybe hit by another vehicle. The preventable accidents could have been avoided (for example the bus hit another vehicle) if the bus driver had exerted more caution. It appears that the number of accidents is dependent on the location (Northside and Southside) and day of the week. The number of accidents in the Southside is more than double that of the Northside.
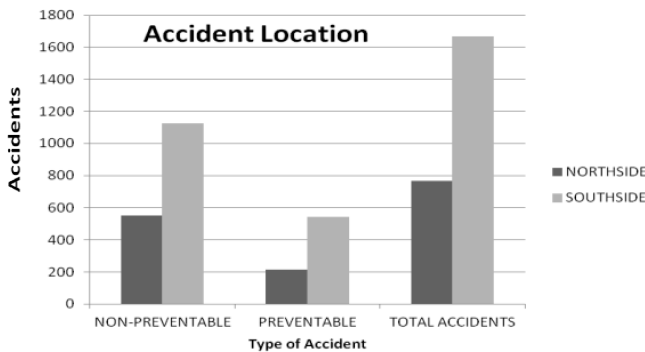
Fig. 6. Location of Accidents.

Some of the preventable accidents have been caused by driver distraction but the proportion is unknown. Researchers have reported that 13.6% of all accidents were caused by distracted driving [2]. The Table 6 has been restructured to reflect the 13.6% distracting activities that caused accudents from 2008–2011:

The factors of the transit bus drivers consisting of demographics and driving pattern data collected through the survey were compared with factors of

other studies to determine their applicability and significance to the current study. The results discussed in the following paragraphs are based on the responses of drivers that participated in the survey, observation on selected routes, and discussion with agency staff members.

The average age of the bus driver was 49 years. The Northside drivers' average age was 47 years and the Southside driver was 51 years. There are a higher proportion of female drivers (54%) compared to male drivers (46%). The average age of male drivers was 50 years and female drivers were 49 years of age. Most of the drivers fall in the 46–55 age groups (Fig. 7). Age is a significant factor related to accidents with younger drivers more prone to accidents and distracted driving [1]. According to the NHTSA [1], in 2008 28% of drivers involved in fatal crashes were under 30 years while only 10% drivers in the 40–49 age groups were involved in fatal crashes. In a study of truck-involved rear-end crash. Yan et al. [26] found younger car or truck drivers (<25 years) are less likely to get involved in a truck crashes compared to middle age drivers (26–55 years), but older drivers (>56 years), are more likely to be involved in a crash as compared to a middle age driver.
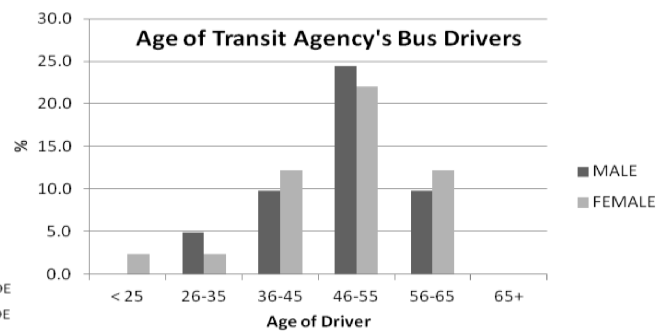
Fig. 7. Age Distribution of Drivers.

A t-test was conducted to determine if the differences in age, experience, and driving hours were significantly different for the Location or Gender. There is a significant difference in driving experience for both locations with drivers on the Southside being more experienced. There is no significant difference in age and driving hours/week between drivers from the Northside or Southside although Southside had slightly older drivers with significantly more driving experience. The drivers reported that they drive a bus for an average of 43 hours per week and that they typically drive the buses mostly during the day (65%) peak and non-peak times and during the night (35%).

Conclusions and recommendations

Developing effective policies and legislation to control cognitive distraction is difficult to implement due to non availability of proper measuring processes [3]. Laws enacted for alcohol consumption and red light running is not as effective for distracted driving since it is more of a societal issue [3].

Policies are needed that limit the distractions that transit driver's experience, including exposure to unnecessary passenger activities on buses. Research is needed to determine the best ways to train drivers to manage and control cognitive distractions in order to avoid reaching the threshold at which mental inattention occurs due to multitasking. This research needs to concentrate on the training of certain populations that tend to have the greatest crash risk. For example, research should be directed towards experienced drivers who may become distracted by secondary activities due to over-confidence in one's driving abilities, or may let their mind wander due to mental or physical fatigue or boredom after driving too many hours in a given week. The need for research also applies to younger drivers who may lack the primary driving skills needed to be able to divert attention to secondary tasks, and older drivers who make take longer to process cognitive information required to drive.

One of the reasons for the high accident rates of inexperienced drivers shown in Fig. 5 are deficits especially in relevant cognitive driving skills [27]. Petzoldt et al. [27] have recommended inexpensive computer based training (CBT) where young inexperienced drivers can experience various forms of cognitive distraction without harming themselves or others.

There was a wide range of distracting activities in the study of the transit agency [7]. This makes communications and outreach programs for the drivers difficult to implement [3].

Distracted driving causes the vehicle to veer outside the lane. In order to circumvent this impact of distraction, researchers have suggested broader shoulders and rumble strips [3]. Fatigue and sickness was noted in the top five distracting rated activity (Table 1). Having rest areas closer apart will allow fatigued/sick drivers to have more frequent stops.

Ranney [3] has proposed *guidelines for Interface Design Vehicular strategies* which focus on internal layout of vehicle systems that could cause distraction such as controls, broadcasting, ticket machine etc. The auto industry in North America and Europe has taken note of such guidelines and are devot-

ing resources *to optimize the interface characteristics associated with in-vehicle technologies* [3].

This is a concept paper on cognitive distraction. The data collected by D'Souza and Maheshwari [7] on the drivers' perception of distraction indicated that cognitive distraction was a major cause. The concepts of cognitive distraction and the modular approach for gaining a better understanding were developed from the works of several researchers [3, 5, 8, 9]. The authors have plans to validate these results using a driving simulator which is planned to be installed on the University Campus.

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INFORMATION MANAGEMENT SUPPORTING MULTIMODAL TRANSPORT UTILIZATION IN VIRTUAL CLUSTERS

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ABSTRACT
Companies are facing problems regarding reduction of their logistics costs. Good organization of transport processes can bring a lot of profits both economical and environmental. Companies participating in transport processes more often prefer to create temporary relations and form virtual cooperation networks than to keep traditional long-term contracts. The paper first defined problems of multimodal transport. The obstacles to development of virtual transport clusters are described. The main problems and requirements of the virtual cooperation in the area of transport processes are identified. The aim of the paper is to present the scope of information needed for the coordination of virtual transport clusters. Author describes approach to information management in virtual cluster based on agent technology.

KEYWORDS
multimodal transport processes, cooperation, information management, clusters, infrastructure, transport policy.

Introduction

Transport is an important element of everyday business operations. At the same times transport operation are generating a lot of externalities to the society like: green house gases emissions, noise, fatalities. The rising congestion on the most of European roads gives impulse to the governments to introduce alternative ways of transport operations organization. During last two decades transport sector has greatly increased its activity. At the same time the efforts made in order to reduce the energy consumption and greenhouse gases emission (GHG) were insufficient. According to data from the European Environment Agency, transport is accounted for close 20% of total GHG emissions (19.5%) and 23.1% of total CO_2 emissions in the EU-27. As presented in Fig. 1 railways, maritime and inland transport have better CO_2 performances than road transport. Taking in consideration that the road transport is dominating, the emissions dispersion is negative.
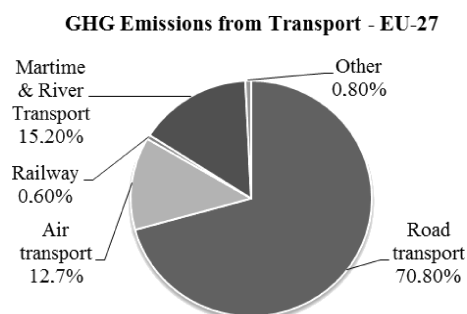
Fig. 1. GHG Emissions from Transport – EU-27 Million tonnes CO_2 (Source: based on data from [2]).

In order to change this negative trend since 2006 the concept of co-modality has been introduced, which requires efficient use of different modes on their own and in combination, resulting in an optimal and sustainable utilization of resources [1]. Dur-

ing last two decades a big progress has been made in achieving the main goals of the transport policy: secure, safe and environmentally friendly mobility. The main goals for improvement are highlighted in number of European Commission documents like:

1. White Papers of 1992, 2001, 2011;
2. Logistics: Keep Freight Moving (2007);
3. Greening Transport (2008);
4. Future of transport (2009).

In March 2011 the European Commission has published new White Paper on Transport. The new transport policy supports also the development of multimodal transport. These goals can be divided into main four directions [3]:

1. reduction of the greenhouse gases emission by 60% by 2050 comparing to the 1990 level;
2. efficient core network for multimodal intercity travel and transport;
3. clear urban transport and commuting;
4. creating global hubs in the European Union for long-distance travel and intercontinental flights.

In order to achieve these goals the European Commission the following action should be taken [3]:

- Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO_2-free city logistics in major urban centres by 2030;
- Low-carbon sustainable fuels in aviation to reach 40% by 2050; also by 2050 reduce EU CO_2 emissions from maritime bunker fuels by 40% (if feasible 50%);
- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors;
- By 2050, complete a European high-speed rail network. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail;
- A fully functional and EU-wide multimodal TEN-T 'core network' by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services;
- By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system;
- Deployment of the modernized air traffic management infrastructure (SESAR) in Europe by 2020 and completion of the European Common Aviation Area; Deployment of equivalent land and wa-

terborne transport management systems (ERTMS – European Rail Traffic Management System, ITS – Intelligent Transport Systems for road transport, RIS – River Information Services, SSN – the EU's maritime information systems SafeSeaNet and LRIT – Long Range Identification and Tracking of vessels). Deployment of the European Global Navigation Satellite System (Galileo);

- By 2020, establish the framework for a European multimodal transport information, management and payment system;
- By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. EU should be a world leader in safety and security of transport in all modes of transport.

The above mentioned actions support the optimization of the performance of multimodal logistic chains. They should also increase the efficiency of transport services and infrastructure's utilization with application of the new schemes for information management.

Multimodal transport operations are carried out in the units codified by the railways of the European countries. These units are: containers large bodywork, car bodies, semi-trailers for semitrailers. At presents over 98% of goods are carried in containers. An essential element of the multimodal transport system is efficient transport infrastructure. The development of multimodal transport requires the consolidation of large volumes for transfers over long distances. Regarding multimodal freight it requires solutions relying on waterborne and rail modes for long-hauls. Integration of network should result in linking of airports, ports, railway. The physical infrastructure should be connected to online information and electronic booking and payment systems in order to facilitate multimodal travel. The multimodal transport is at present often not economically attractive for shippers, especially for short distances. The challenge is to improve the economical attractiveness and service quality for maritime, inland and rail transport in order to take a significantly greater proportion of medium and long distance freight. By 2050, all core airports should be connected to the rail network (high-speed if possible) and all core seaports should be sufficiently connected to the rail freight and, where possible, inland waterway system. For freight transport, an intelligent and integrated logistics system which support multimodal transport are needed.

This paper research highlights concentrate on:

- Identification of the main barriers to the multimodal transport development,

- Analysis of the state of the development of the multimodal transport in Poland,
- Identification of requirements for information management by organization of the multimodal transport especially by small and-medium sized companies,
- Overview of communication standards applicable in the conditions of virtual clusters,
- Identification of the information gap by information exchange by organization of multimodal transport within virtual clusters,
- Examination of the potential of agent based systems for coordination of virtual multimodal transport cluster,
- Proposal of standard messages implementation for information management in virtual multimodal transport cluster.

Barriers of multimodal transport

The importance of the multimodal transport is highlighted by a number of legal documents at the European and national level but still a number of barriers exist. The main of them are presented in Fig. 2. The problem tree analysis was applied to find the causes and effects of relatively low development of the multimodal transport in European Union and Poland. The advantage of problem tree analysis is the possibility to break down particular complex issue into manageable and definable chunks. This enables a clearer prioritization of factors and helps focus on objectives.
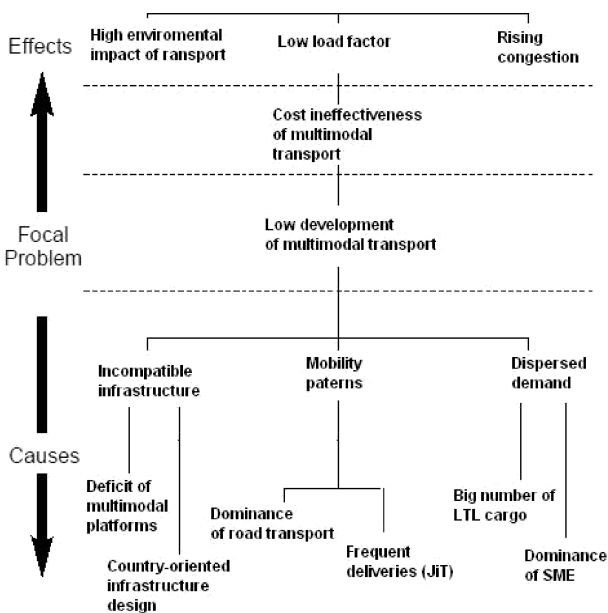
Fig. 2. Problem tree analysis- low multimodal transport development.

Most of the existing transport infrastructure has been designed to serve national rather than European economy. There is the lack of comprehensive standards on infrastructure design, power supplies, traffic management and data exchange, that result in cross border bottlenecks that constrain the movement of goods. In last decade the application of Cohesion Fund and European Regional Development Fund has helped to developed Trans-European transport networks (TEN-T). The cost of EU infrastructure development to match the demand for transport has been estimated at over € 1.5 trillion for 2010–2030. The completion of the TEN-T network requires about € 550 billion until 2020 out of which some € 215 billion can be allocated to the removal of the main bottlenecks (based on data from [3]). There is still need for additional investment in the infrastructure in order to create co-modal logistics chains which optimize the use of the different modes. The main shortages appear in the following infrastructure:

- multimodal nodes for rail and sea or air transport;
- IT infrastructure supporting intermodal transport.

The efficient transport system requires integration and interoperability of the individual parts of the network within Europe. There is deficit of platforms integrating different modes of transport. Crucial in achieving this result are the logistics centres which play the role of the network's nodes. Nowadays there is still scarcity of multimodal and transhipment platforms which can consolidate and optimize passenger and/or freight flows in the urban areas in order to avoid frictions. A big problem is disconnected planning at national and European Union level. According to the Impact Assessments analysis performed by elaboration of the new transport policy the following inefficiencies appear [4]:

- lack of joint traffic forecasts leading to differing investment plans;
- incompatible technical characteristics of new infrastructure;
- inadequate joint management of cross-border infrastructure projects.

The main challenges regarding the infrastructure development for multimodal transport include:

- creating platforms connecting airports and ports with efficient rail services;
- establishing the framework for a European multimodal transport information, management and payment system attractive frequencies, comfort;
- incentives for companies for usage of intermodal transport;

- easy access to services;
- smart inter-modal ticketing, with common EU standards.

The mobility patterns are based mainly on the road transport for freights especially on short and medium distances. Entrepreneurs, without the improvement of their financial results, are not interested in using alternatives to road freight transport. According to the European Commission the share of road transport in total freight is at the level of 76.9%. At the same time the share of rail is only 17.6%. The current capacity of transport networks is not able to meet the growing demand, what causes congestion in urban areas and on the key transit roads. The journey times lengthen and reliability suffers due to the fact that the effective organization of the transport processes is more and more difficult. It is a challenge to persuade the entrepreneurs to move traffic from the road onto rail, inland waterways or short-sea shipping. The multimodal solutions include for example road-rail transport, where on the main part of distance is used rail transport, while road transport is used only for cargo delivery from rail siding to the final recipient. The modern logistics trends based on frequent deliveries, like for example just in time (JiT), also discourage the application of multimodal transport. According to the data from the Office of Transportation (UTK) the average distance of multimodal freight in Poland was 415 km [5]. In short distances the multimodal cargo is usually cost- inefficient.

Intelligent mobility and transport demand management solutions might help to lower the congestion. There is still lack of the cooperative systems based on vehicle-to-vehicle and vehicle-to-infrastructure-communications that might in the longer term improve considerably the efficiency of traffic management and alleviate congestion [1].

Among European companies over 99% are small and medium sized enterprises. This situation leads to the dispersion of demand for transport services and a big number of the LTL (less than container load) shipments. Research conducted in the last decade by the European Environment Agency has indicated that in most countries of the European Union use of available capacity of operated means of transport is low. According to EU statistics the average use of available capacity of vehicles is at 54%. For rail transport, this value is 48%.

A challenge is to find solutions which might help to encourage the SMEs to cooperate in order to integrate the dispersed demand.

State of on multimodal transport in Poland

Poland is second biggest market for rail cargo volume in Europe and the fourth biggest regarding the length of the rail network, but despite this fact the share of multimodal transport freight is very low. At the end of 2011 the share of multimodal transport in rail transportation was 4.53%. It was one of the lowest results in the whole European Union. In countries where there is efficient State aid for greening of transport, intermodal rail freight exceeds 20%, and in some countries, such as. Netherlands, Spain, Belgium, fluctuates at 35–38%. Lower share than Polish intermodal market, is noted only in countries with poorly developed network rail infrastructure: Estonia, Finland, Latvia and Lithuania.

In recent years Poland has one of the highest rates of growth for multimodal freight. It was significantly higher than in most of the European countries. In Poland in the years 2009-2010 increase of traffic amounted to about 30% in the same period, comparing to less than 12% in Germany 5.4% in Belgium and in Netherlands at 0.4%. The average growth rate in all European countries in the years 2009-2010 has been fluctuating at 10.8% [5]. However the basis for this growth was very low. In the year 2009 the multimodal freight in Poland was 1449 million ton-kilometers (1888 million tkm in 2010) comparing the Germany 27 918 millions ton-kilometers (31 126 million tkm in 2010) at the same time.

In 2011 in Poland were 28 containers' terminals suitable for intermodal transport [7]. Terminals belong to the different operators, like: PKP Cargo S.A. and CargoSped Sp. z o.o. or PCC Port Szczecin and ACIS Holding S.A.. Some additional terminals are operated by the local companies. At the same time 26 of them were actively used by rail to shipped approximately 800 thousand units of the TEU in 2011. Four maritime containers' terminals in Swinoujscie, Szczecin, Gdansk and Gdynia reloaded 1357 577 TEU (twenty feet equivalent unit).

Main limitations for the increasing of the multimodal freight are poor technical conditions of the terminals mainly due to low capacity of warehousing space, the poor quality of the surface of reloading places, the lack of appropriate handling equipment and insufficient railway infrastructure, for example the lack of a suitable length of track for and landing facilities (above 600 m trains). The biggest disadvantage affecting significantly the volume of multimodal transport is also the lack of a sufficient number of national and regional centers. The next problem is the low speed of such services. Average speed of rail

freight services in 2011 was 25 km/h and an intermodal container transport was around 35 km/h. In Germany for example the average speed for multimodal freight services varied between 60–70 km per hour.

Due to the high costs of transport by rail, road transport and poor quality of disproportionate to the parameters of the railway lines (including the average commercial speed), the carriage of containers on short distances are uneconomic. Intermodal transport increase profitability along with the distance of carriage. Most of intermodal services performed by Polish companies are international (about 80%). The domestic multimodal freight is about 20%.

The problems identified in the previous section also applied at multimodal transport in Poland. In the next section some solution regarding the aggregation of the demand and improvement of the infrastructure are discussed.

Virtual clusters – basic definitions

The European Union promotes cooperation among small and medium-sized enterprises (SMEs), which usually have less money for infrastructure expenses. SMEs have usually worse position in the negotiation regarding multimodal freight conditions due to the small volumes of cargo. Consortia of the small shippers consolidating their shipments may reach much better freight rates thus becoming much more attractive partners for these carriers [8]. Internet gives SMEs possibility to built temporary networks. Open web-based solutions don't require investments in infrastructure. Access to the broadband Internet usually is the only limitations to use them, and it is easy to overcome.

Traditionally clusters are understood as geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field that are present in region [9]. Virtual logistics cluster can be defined as a temporary network of individual companies, which aims to gain the benefits of economy of scale by joint execution of goods transfers to (or from) the particular geographic region.

By creations of the virtual clusters the SMEs can benefit from lower costs by assuring frequent deliveries. The additional benefit is limitations of externalities like GHS emission, noise and congestion reduction by elimination of empty routes or increased load factor.

The virtual logistics clusters have following characteristics:

- they should be technology independent by data exchange;
- they should be able to exchange information in visible and secure way;
- they should be opportunistic by network configuration – any time companies evaluate the benefits of participation and are able to reconfigure the network by each contract.

The temporary nature of the cooperation requires low-cost, technology independent common standards for data exchange and communication.

The standardization and interoperability problems are described in the next section.

Information management by multimodal transport

Multimodal transport organization involves usually transport service providers (supply side), transport service clients (demand side) and coordinators of multimodal services. The information requirements are different:

- transport service provider (TSP) – searches for additional orders to increase load factor;
- transport service client (TSC) – searches for freight rates, delivery times, payment conditions and reliable transport providers;
- multimodal transport coordinator (MTC) – searches for current offers and orders to match demand and supply side.

The typical information systems used for transport planning and execution can be divided into:

- transport exchanges;
- transport routes planners,
- intelligent transport systems,
- internet platforms for demand aggregation or transport mode choice.

The multimodal transport organization requires search for a combination of different modes, in order to meet the minimal transit time or transport cost. Also the structure of stakeholders is a rather complex. For example transport service providers (TSP) in order to use all modes of transportation applied very often sub-contracting. Beside direct carriers owning owners of transport modes there are numerous companies who are integrators and offer door-to door transport service subcontracting selected carriers on particular sections of the route.

There are more and more examples of Internet platforms which support the multimodality. One of such examples is Logit4see [8] tool which helps to make optimal multimodal choice. This tool [8, p. 8-9] provides the optimization of a multimodal sup-

ply chain according to the following basic logistics processes:

- Operational Planning – selecting the optimal transport chain regarding delivery time or cost
- and booking loading surface with them;
- Transport execution – after acceptance of transport order system allows to monitor transport progress and to reschedule the chain when deviations appeared;
- Freight transaction completion – after accepting Proof of Delivery by a receiver it allows possible claims settling , invoicing and payment.

One common problem which appears by information management is lack of interoperability. The number of interactions by multimodal transport organization requires the electronic data exchange. Co-operating companies both TSP and their clients need common set of electronic messages and common identifiers. Standardization is a must, otherwise it would be difficult to cooperate in virtual logistics cluster and meet requirements of ICT systems interoperability. Standards are understood, as predefined and agreed structure and content of messages/documents regarding booking of resources and services as well as reporting status on the performing of transport services.

Pedersen [10] has indicated: standardization organizations describe their electronic documents through specifications and implementation guidelines. Interoperability is defined in this chapter as: "the capability to run business processes seamlessly across organizational boundaries. Interoperability is achieved by understanding how business processes of different organizations can interconnect, developing the standards to support these business processes

efficiently and by specifying the semantics of messages exchanged between the organizations to support these business processes in a scalable way" [10].

Interoperability of information systems enables formulation of virtual networks. It is chance for small and medium sized enterprises to implement and connect to and to be part of efficient multimodal logistics networks.

Communications standards

In the field of logistics many standards are already defined. There are over 400 standardisation initiatives recorded in the world [11]. In Europe big sized companies more and more often use the Logistics Interoperability Model (LIM) by GS1 [16]. Small and medium companies (SME) still search for the other solutions that might be suitable for them. Standards define mainly format and structure of information which is exchange among cooperation companies.

One of the recent initiatives regarding standardisation of logistics is a Common Framework for ICT in Transport & Logistics. It provides interoperability and consists of roles, business processes, ontology and messages to support interoperability in the main logistics processes, providing the information infrastructure to support mode-independent transport planning, compliance, cargo consolidation and visibility [10]. The Common Framework has a vision to become an umbrella of all major existing communication standards. Table 1 presents the most common messages used in Common Framework for communications when organizing multimodal transport services.

Table 1
Examples of standard messages in transport process developed within Common Framework

Name	Purpose	Scope
TSD (Transport Service Description)	TSD is used for a description of transport services suitable for automatic detection. It applicable for transfer of, operations in terminals, discharging, and additional services.	Description of service including: – scope of services, – prices, – type of cargo (food, electronics, ADR ect.), – type of packing units (pallets)
TEP (Transport Execution Plan)	TEP describes all the information needed related to the execution of a transport service between transport user and transport provider.	
TES (Transport Execution Status)	TES provides information about the progress of the transport and of the cargo condition	Remarks about the execution of the transport service, special conditions, delivery time, delivery location
GII (Good Item Itinerary)	Provides information on the movement of goods on the whole way including transhipments	Description of the complete itinerary for a given goods item, including planned, estimated, and actual times for departure and arrival for each service.
TOS (Transport Operation Status)	TOS assists in establishing the best possible arrival time estimates.	Reports on transport execution status including deviations from planned routes and timetables.
TNS (Transportation Network Status)	TNS points out traffic, including information from the different transport modes.	Information on vehicle movements, obstacles, traffic jams.

The communications standards are recognizes mainly by big companies. The small and medium companies used mainly the standards of big companies they cooperate with. The pilot survey was conducted among group of about 30 companies from SME sector. The companies represent both transport clients and transport providers. The research highlights the information exchange between the transport service client and transport service provider. The group of respondents was asked about the application of common standards. The results are presented in Fig. 3.
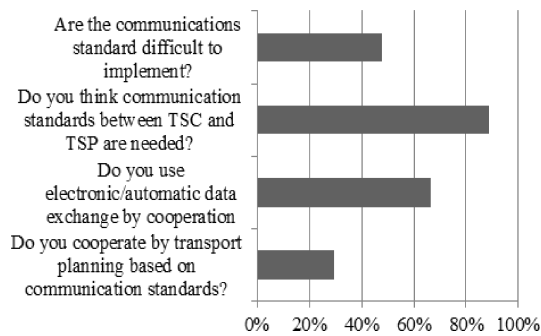
Fig. 3. Positive answers regarding the implementation of common communication standards.

Fig. 4. Implementation of the communication standards from Transport Service Clients (TSC) perspective.

Fig. 5. Implementation of the communication standards from Transport Service Providers (TSP) perspective.

The companies are not very familiar with communication standards (c.a. 30%). At the same time most of companies (almost 90%) have declared that common communication standards are needed. The most

common is electronic data interchange (c.a. 65%). In Figs. 4–5 are identified main barriers and advantages of communication standards implementation.

Information management in virtual cluster

The information management within virtual cluster aims to enable companies to achieve synergy effect leading to increased efficiency comparing to the independent activities. Moreover due to the temporary nature of cooperation and opportunistic behavior of the companies participating in the cluster it requires the flexibility and ability to adjust to changing situations.

The main functions of tool for information management for multimodal transport within virtual cluster are: freight aggregation, multimodal transport chain planning; electronic tender for intermodal transport services; offers consolidations and networking.

Information gaps regarding organization of multimodal transport within virtual cluster are presented in Table 2.

Often problem is a lack of the coordination and integration between the information systems working between virtual cluster members. Moreover the transport demand is not constant. Agents' technology is useful in case of changeable events management. It can be stated that following characteristics are typical for multimodal transport coordination within virtual cluster:

1. data, control and resources are inherently distributed,
2. the system is regarded as society of autonomous cooperating entities,
3. the components must interact with other to reach whole system goals.

Table 2
Information gap by information exchange by organization of multimodal transport within virtual clusters.

Information gap	MTC	TLC	TSP
Availability of multimodal infrastructure	X	X	
Status of multimodal network	X	X	
Current multimodal transport demand	X	X	
Current multimodal transport offers	X		X
Possible multimodal partners (capacities overview)	X	X	
Possible demand aggregation	X		X

Agent technologies can be used to facilitate and control the scope, the time, and the frequency of in-

formation sharing based on specific arrangement of each partners. The characteristic of agent technology suits well to perform planning and coordination in a multimodal virtual cluster where we can observe [12]:

- heterogeneous environment
- open and dynamic structure
- interoperability of components
- need for scalability.

The distributed multi-agent system is suitable to perform inter-organizational planning of multimodal transport processes.

Agent technology is the preferable technology for enabling a flexible and dynamic coordination of spatially distributed entities [13]. The mentioned above characteristics suit well to requirement for planning and coordination of intermodal transport process. In an agent-enabled environment, the multiple transactions and exchanges of information that drive material flow can be managed by software agents that maintain visibility across the network [13].

Agent-based system architecture provides an interesting perspective for integration of the companies in virtual clusters because agents are able to generate, process, filter, broadcast, and correlate information for real-time coordination. In this paper an agent-based system is understood as a multi-agents system that's utilizes databases of business applications implemented in cooperating companies. An agent is defined as "computer system situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives" [14]. Agents are reactive, proactive and have social ability [14].

Interoperability is needed in virtual clusters in order to safely exchange data between the different information systems. The data should follow predefined structure in order to create useful information. Communication between IT systems is possible independently of programming languages, platforms and operations systems they use, and applied information exchange standard [15]. All the above mentioned features make the semantic web suitable for application the in virtual networks. The access to the semantic web does not require application of any specialized IT systems. Information can be process in format that is readable and understandable for computer and any user. This solution gives SMEs a better possibility to capture information and exchange them within particular enterprises' network, as well as it helps to build up business relations [15].

A feasible and low cost solution for information management in virtual cluster is application of web platform. Suitable solution might be an hy-

brid of web-services and agent technology. Simplified schema of such tool is presented in Fig. 7. The solution includes agent representing different roles:

- Multimodal transport service coordinator agent (MTCA) - it is responsible for cooperation, communication, negotiation on behalf of cooperation entities. It delegates collecting of predefined information scope about potential business partners. It makes decisions regarding follow-up actions. Coordination Agent cooperates with groups of all agents.
- Transport service client agent (TSCA) – it is responsible for issuing the demand for transport service and it defines criteria for acceptable transport chain scenarios, as well as potential cooperation scenario with other clients.
- Transportation Service Providers Agent (TSPA) – represents companies which offer particular transport services, it defines structure of transport offers and possible/potential scenarios to create transport chain.
- Informing Agent (IA) – it is responsible for sending information to MTCA about new attractive offers available, as well as for informing transport clients agents and transport providers agent about the possibility of starting cooperation with MTCA after fulfillment of defined criteria. It makes semantic verification of information placed in the web by cooperating entities.

The communication between agents and user is asynchronic, so the confirmation of message by receiver is not required in order to continue the process execution [15]. Agents and users are informed automatically about any new event e.g. new offer arrival.

In Fig. 6 the schema for information exchange between network participants is described.

Application of the agent-based system and semantic web allows the improvement of organization of the multimodal transport process. The procedure below presents the process of multimodal transport planning by agents (see Fig. 6):

1. Transport service clients order their agents (TSCA) to issue demand and to define acceptable chain for multimodal.
2. MTCA collects the offer and aggregate them in orders to create virtual cluster.
3. MTCA sends the cluster formulation proposal for particular multimodal transport service to TSCA.
4. MSCA sends to TSPA join demand definition for multimodal service.
5. MTCA through hyperlinks finds ontology defining key words. Then it communicates with TSPA representing potential service providers and collects their offers and passes them to MTCA for analy-

sis. MTCA receives to the inquiries offers for the whole route or to the part of it.

6. Before offer choice MTCA questions providers agent TSPA whether the offer is still valid. If not, then the whole procedure needs to be repeated. If the offer is still valid, then the appropriate resources are booked. MTCA can book multiple carriers, and form multimodal transport chain (cluster at the providers side) in case when individual carrier is not able to provide multimodal transport service. Particular TSPA can create intermodal transport cluster or act separately in case they offer multimodal services

7. If the negotiations are successful, then the cooperation starts and agents sign the commission of service purchase on behalf of companies they represent. When the transaction is finished, MTCA stores the scenario of acceptable multimodal transport chains in its database. Collection of scenarios helps to simplify the negotiation process in the future.

As mentioned before a interoperability is needed by usage of predefined messages structure. Application of Common Framework messages (see Table 1) for the model is presented in Fig. 7.

Presented in Fig. 7 approach allows to plan and execute multimodal transport services in virtual cluster. Due to the standardization of message structure and format they are easy understandable by any system and user. So it allows fulfilling the requirements for technology independency. The company might benefit from dynamic reconfiguration of cooperation network by organization of multimodal transport.
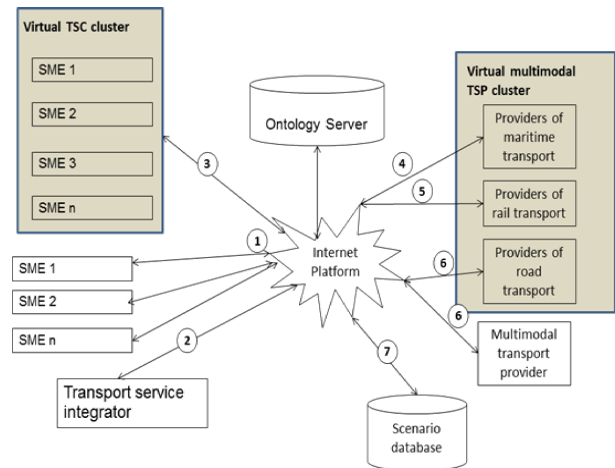
Fig. 6. Model of multi-agent system based on the semantic web (source modified from [15]).
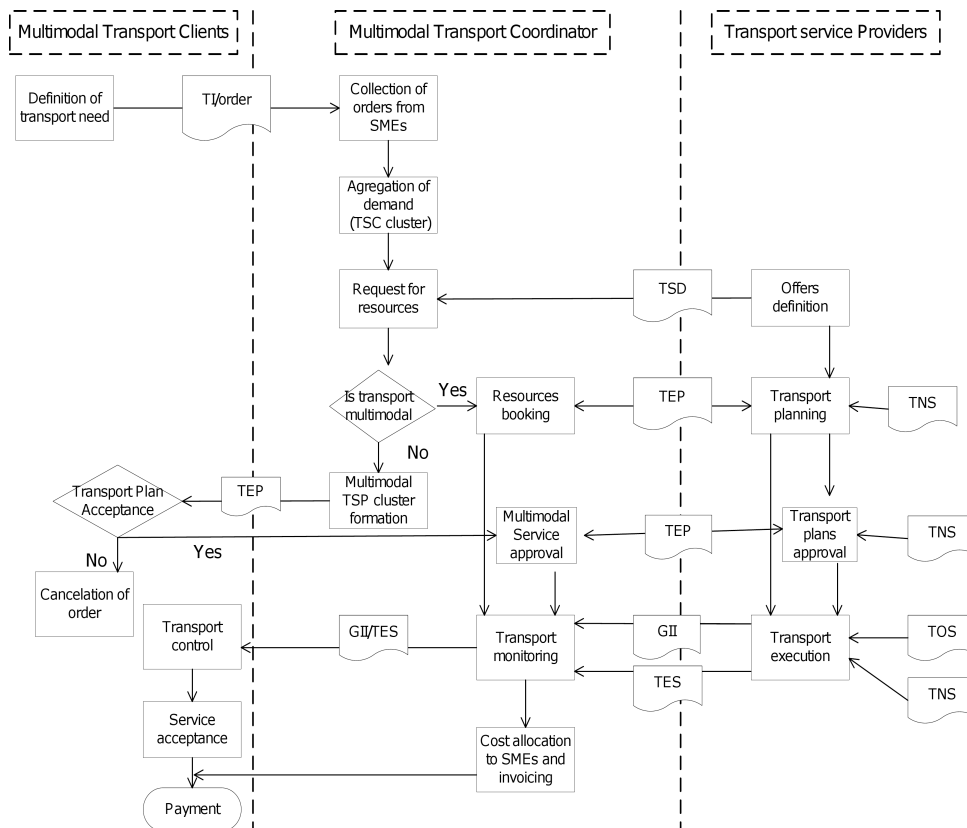

Fig. 7. Example of standard messages implementation for information management in virtual multimodal transport cluster.

Conclusions

The paper presents the problem of virtual clusters formulation by organizing of multimodal transport. The main research findings are:

- identification of the obstacles to development of virtual transport clusters,
- detailed description of the problem of standardization of information in transport processes especially by small and medium sized enterprises,
- elaboration of the concept of application of agent-based model with usage of standard messages for information management in virtual multimodal transport cluster.

Author highlighted how the lack of consistency of business process performed by particular entities and the variety IT systems used by companies, cause problems with automatic partners networking. As mentioned before small and medium sized companies have usually weak negotiation position by multimodal transport booking. Also at the supply side some transport service providers are not able to offer multimodal service on the whole route. The advantage of virtual cluster is the opportunistic approach of the participating companies so different transport chain scenarios can be created, including wide range of transport options offered by all modes of transport. Proposed model provides stakeholders with an extensive knowledge by automatically configuring multi-modal operable supply chains. Proposed solution enables efficient creation and automatic collection of data about companies and their resources published in the Internet. It facilities the establishing of the temporary cooperation network named as virtual logistics clusters. Agents representing particular companies coordinate and establish cooperation's conditions, in order to reach common goal of cost effectiveness.

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THE ROLE OF MANUFACTURING TECHNIQUES IN ENTERPRISES PRODUCING HEATING DEVICES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

Manufacturing techniques are concerned with quality, cost, productivity and sustainability. With today's environmental awareness and the pressure of the sustainability requirements, existing manufacturing techniques of heating devices are evolving into the redesign manufacturing unit processes to increase overall sustainability. Also, these techniques need a measurement method to assess processes-related sustainability performance indicators.

The purpose of this paper is to stress the role of manufacturing techniques: welding, cleaning and painting in the manufacture of heating appliances (solid fuel fired boilers used renewable energy sources) in terms of incorporating into the field the concept of sustainable development. It then focuses on the environmental, technical, economical and social impact of sustainable technologies and argues for the need to ensure that the concept is being applied to the manufacture of heating devices.

In this paper, author tries to propose a unified, standard scientific factory-level methodology to evaluate the influence of manufacturing techniques on the sustainability of enterprises producing heating devices. The proposed methodology in the terms of the case study is a comprehensive answer to the question of to what extent the improvements in those techniques influence the sustainable development of the enterprises. An industrial case study demonstrates that the proposed improvements can effectively influence the sustainability of enterprise. The results of this assessment can be applied to broad industry sectors, and can lead to the accepted measures and practices.

KEYWORDS

manufacturing techniques, sustainable development, welding, cleaning and painting processes, heating devices, environmental impact, life cycle assessment (LCA).

Introduction

As a result of discussions from European regulations related to environment and health, sustainable techniques and technologies has become a strategic move as industries begin to seek novel ways to make an efficient use of resources, ensure compliance with regulations related to environment and health, and enhance the quality of their manufacturing processes. The idea of introducing sustainability in manufacturing processes planning and scheduling, where cost, quality and lead time, and energy are needed for the unit manufacturing processes performances assessment towards sustainability, which was proposed by Mani and Lyons [1]. In the pursuit of sustainable development in manufacturing processes (called also sustainable manufacturing), this paper aims to emphasize the importance of welding, clean-

ing and painting techniques on the need to meet the legal regulations and requirements of different manufacturing installation/equipments used to produce heating boilers. It has been noted that in production process of heating appliances, manufacturing techniques have the potential for significantly improved environmental and social performance relative to other technologies. So, these techniques give considerable attention to the sustainable development of manufacturing enterprises.

The other aim of this paper is to show a case study towards implementing the sustainable development in enterprises. Hence, the scope of the paper is being limited to a case study – based on the discussion of the role of the welding, cleaning and painting techniques in terms of the sustainable development of an enterprise.

The production of boilers can contribute to the development goals of the three-pillar model and can be assessed in terms of an exact impact on the sustainable development of enterprises. Welding, cleaning and painting techniques are the main causes of the consumption of the resources, materials and toxic waste generated by the surface preparation methods of metals and application method, which, in turn, are the side effects of the production process. Possibilities of change of the production processes of heating devices appear in the improvement of manufacturing techniques and technologies to optimize production and to accommodate the new needs of sustainability. On the other hand, requirements of changes of the existing technology are determined by governments that promulgate the environmental interests to reduce emissions and toxic waste being generated by the surface treatment.

These aspects underline the need to assess both the technical, environmental, economical and social impacts of these manufacturing processes to ensure that welding, cleaning and painting technology deployment remains aligned with overall sustainable development goals. The STPI white papers also stressed the "need for accessible and affordable measurement systems and analytical tools for assessing (. . .) and across the production process" [2] in the context of the sustainable development.

Currently, a Life Cycle Assessment Methodology is an assessment tool of business activity, assuming the depletion of natural resources and the impact of pollutants as criteria for evaluation of the business activity [3, 4]. The methodology ensures the comparable results by consideration the environmental problems in industrial plants, but according to Finnveden an assessment evaluates the significant environment impact of throughout the product's life

cycle, including human health, and resources [5]. Another approach proposed by Hui et al. [6] limiting their model to the environmental hazards in manufacturing. The network analytic method with a numeric fuzzy weighting factor was employed to determine and analyze the potential of each impact category created by different kinds of waste in manufacturing processes [7].

In Jawahir's work [8] there have been attempts taken to evaluate the degree of sustainability of the given manufacturing process, namely machining whereas the Office of Science and Technology Policy report has highlighted the need for the accessible measurement tools for assessing and managing the sustainability across the production process supporting the advanced manufacturing. But none of these known methods did consider an influence of the technological factors on sustainable development on enterprises.

The meaning of sustainable development in manufacture

Since the Brundtland Commission popularized the term of sustainable development in 1987, the concept has increased extensively and it features more and more as a core element in policy documents of the governments. It follows the Brundtland definition that development is sustainable if it "meets the needs of the present without compromising the ability of future generations to meet their own needs". A growing environmental damage caused by the increase in production could be reduced by the sorts of technological changes. But the growth is possibly through the powers of appropriate techniques and technology, which allows finding new sources or providing alternatives if a particular resource appear to be running out.

In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and the future potential to meet human needs and aspirations" [9]. Sustainable development in manufacturing techniques requires "improvements in material, resource, and energy efficiency, adequate reductions in exposure to toxic substances, significant opportunities for stable, rewarding, and meaningful employment with adequate purchasing power (. . .)" [10, 11]. The use of manufacturing techniques and technologies which require less energy, water as well as wastes would lead to decrease in burden of environment. The report of Our Common Future UNCED calls also for "recog-

nition of the concept by business" [12] and solutions to urgent environmental and societal problem [13]. This need to incorporate the concept of sustainable development into the enterprise level, combined with several dimensions to sustainable development, resulted in the principle of so-called triple bottom line[1] [14, 15]. This concept is based on the description of three factors: the financial result (profit) combined with social responsibility (people) and concern for the ecological dimensions of activity (planets) that should form the basis for measuring and evaluating the functions of enterprises; economic, environmental and social in sustainable development. According to these concept actions taken by industrial facilities through the use of sustainability drivers (environmental, economic and social) create advanced products, production technologies and new market places [16]. Furthermore, in the sustainable development context, technological aspect is viewed as one of the four dimensions of sustainability concentrating on the design of devices, technologies and systems to produce more social goods with less environmental harm. It means designing technology by reducing material consumption, energy intensity of production, prevention of pollution at each stage of manufacturing processes over the rational use of natural resources. Techniques and technology can be successful in the closed-loop system if at least three dimensions appear (environmental, economic and social) as well as "if its aims are directed toward the system as a whole rather than at some apparently accessible part" [17].

Requirements of the sustainable development in manufacturing processes are focused on the utilization of available resources and the generation of new resources, decision-making aspects such as supply chain, quality initiatives, environmental costing, and manufacturing techniques assessment.

Review on sustainability of welding, cleaning and painting techniques

With initiated R&D programmes launched in European Union (EU) are covering objectives with environmental requirements.

The importance of production techniques (Best Available Techniques) was underlined by U.S. Environmental Protection Agency (EPA) in the Sec. 5 of Environmental Protection Agency Acts, 1992 and 2003, as the "most effective and advanced stage in the development of an activity and its methods of operation, which indicate the practical sustainability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impact on the environment as a whole" [18]. EPA gives regard to the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and humans, and the use of low-waste technology, while Cleaner Production – greater overall efficiency through improved production techniques and technologies, including modifying manufacturing process, upgrading equipments or substituting different materials. This new dimension called sustainability was remarked and added to manufacturing industries. Pekkari states that the driving force behind the sustainability in manufacturing demands are among all quality, productivity and working environment [19].

In Poland, the current sustainability awareness in manufacturing unit processes, mainly welding, cleaning and painting is fairly low. The society is however much more concerned about the environmental aspects. These drive for a continuous development of the manufacturing processes and applications.

The environmental impact of the cleaning and painting technologies depends on the volatility of the compounds used. From the environmental perspective, cleaning and painting systems have produced hazardous waste and releases of toxic chemicals to air and solid media. From the economic viewpoint, energy enables the manufacturing operations add value to the intermediate products. The design features of many technologies or improvement of existing techniques reduce employee exposure to any hazards posed by the use of paints.

The associated environmental aspects of welding generating toxic fumes during the welding job can adversely have an impact on the environment/ air quality and solid waste which can result in land abuse if not disposed properly. The hazards will depend on the type of welding, the materials (base metals, surface coatings, electrodes) to be welded, and the environmental conditions (outside or in a confined space). Use of local exhaust ventilation removes fumes and gases at the source. However, general ventilation is not as effective as local exhaust ventilation, but often it is helpful when used to supplement local ventilation.

Welding is primarily considered to be a "health and safety" problem, which is noted in the allocation of responsibility for sustainable development. Even

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[1] "Triple bottom line", a concept for reporting business activities, introduced by John Ellington and described in his book titled: Cannibals With Fork: The Triple Bottom Line of 21 Century Business, New Society Publishers, Stony Creek, CT, 1998.

though we are fairly slow in implementing the environmental programmes in the welding industries, we have major challenges in developing the joining processes [19]. Then, the impact on the environment could be reduced greatly. For example, in the Junbeum's et al. paper [20], within forklift manufacturing unit processes, cutting, welding and painting had the highest impact on the values. In order to minimise the environmental impacts, a new paint was created with an increased solid content over the existing solvent paint used in the painting process.

In manufacturing of heating devices, the most common method for preparing the steel surfaces for painting is sandblasting, preceded by vapor degreasing to remove any oily film present [21]. Sandblasting leads to create the amount of hazardous dust, hence, abrasive-blast treatments (by shot blasting machine) would be seen as the best treatment. In this type of application, solvent (xylene or toluene are preferable solvents) wiping should be used only as a last resort. Solvent cleaning removes all visible oil, grease, soil, cutting compounds and other foreign matter from surfaces. Solvent degreasing has to be upgraded according to the provisions of the solvent emissions. Chemical treatments for non alloy quality steel[2], mentioned in the Engineering Handbook [22], are to be used only when abrasive equipment is not available. Finally, painting technology should be used.

Shot blast media can be recycled, generate less waste than sand blasting, and it is cheaper than the compared one.

Wet painting is a traditional method applied: water based or solvent – based paints to a surface.

Metal painting generates quantities of liquid waste and harmful vapors thereby influences the human health and the natural environment by air and groundwater pollution. If solvent-based paints must be used, airless spray guns or air-operated spray pump application technologies should be treated as a high transfer efficiency. It allows to save the paint material (30–50% compared to the air spray, and both application technologies produce a higher film build than air spray) [23].

Because of the hazards to the community associated with the chemicals during the paint application, the best way to reduce vapors and volatile organic compound emissions (acetone, toluene, xylene) is the use of an installation (paint spraying and drying booth with its own air supply and exhaust fans and with its own heating system) which meets the requirements of the industry regulations and environmental regulations, in particular: due to fire safety, worker safety, quality of products, less use of painting materials, lower emissions of volatile substances into the air. On the other hand, to cut a significant cost of the pollution control investment, the use of powder or high-solids paints is being recommended instead of solvent-borne options which would improve also the efficiency of the pollution control systems. In this aspect the investment decisions play a crucial role in the heating industry.

The above review is generally attempting to describe the environmental aspects of manufacturing techniques and lets appear how to implement various technologies in order to improve sustainability level. It means that the literature of sustainability of manufacturing unit processes is missing a standard, structured assessment methodology that enables to assess the current state of techniques and technologies and defines the impact on sustainability. Moreover, the current use of ad-hoc methods does not consider the technological factors of sustainable development of the manufacturing enterprise. Additionally, they are used, not only for evaluating the environmental impact on the manufacturing processes, but also for selecting processes when the environmental impact is one of the factors to be considered. According to the concept of sustainability, all three factors (environmental, economical and social) must be integrated in the manufacturing domain.

This paper presents a measurement method to fill this required gap.

Methodology for analyze and assessment of manufacturing techniques

For this research, welding, cleaning and painting techniques have been studied for one of the leading heating boilers manufacturers in Poland with a very high manufacturing potential. The enterprise run in the Lublin Region has developed a lot of new products not only pellets, wood fired boilers but also biomass. The analysis and assessment were framed in terms of technological changes in manufacturing techniques for the enterprises. It has been viewed as goals that should be achieved for the manufacturing processes to contribute to the sustainable development of the enterprise.

The potential improvement actions of welding, cleaning and painting techniques will facilitate to achieve a pathway towards environmental, social and economic development. The choice of the best option

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[2]In accordance with EN 10020, P235GH, P265GH, P295GH and P355GH are non alloy (carbon) quality steels to operate at an elevated temperature. All of other grade are alloy special steel.

(installation) was assessed by taking into account the economic and technical viability of upgrading existing installations as well as environmental regulations.

Interpretation of components for sustainable development

The importance of welding, cleaning and painting techniques with respect to sustainability can be assessed in terms of the sustainable development perspectives. The investigation was done in the form of case study.

Based on the literature concerning the sustainable development issues, there were four perspectives of sustainable development and their components distinguished. While three perspectives are typical for the assessment of the manufacturing techniques, the author has proposed one more perspective (technical) stimulating the sustainable development in the manufacturing enterprises to complement and detail the components.

Classified components according to the four perspectives (and their indicators): technical (I_{TECH}), economical (I_{ECO}), environmental (I_{ENV}) and social (I_{SOC}) are shown in the Table 1.

Each perspective has been given a value of indicator expressed by a 5-point scale. It has allowed to compare the cleaning and painting in the context of perspectives of the sustainable development.

By this means, the development of the perspectives of the enterprise sustainable development as well as the principles underlying sustainability assessment as well as rating can be traced and understood.

Calculating

The paper shows the unit manufacturing processes that affect the production process of heating boilers as shown in the Fig. 1. Identification of the unit manufacturing processes helps the enterprise to take the remedial action by prioritizing the most occurring and influential ones through production. Measures were identified for manufacturing processes like: cutting, welding, cleaning and painting. Bending and final assembly processes were not evaluated due to low air pollution emissions and little or no harm to human health.

To assess the impact of manufacturing techniques on the sustainable development of enterprises in terms of environmental, technical, economical and society the scoring method was used by a 5-point scale, defining (in points) the impact as: 1 – slight, 2 – small, 3 – medium, 4 – large, 5 – very big.

Table 1
Classified components of sustainable development of enterprise

| Technical perspective	Economical perspective	Environmental perspective	Social perspective
✓ Size and capacity of the facility ✓ Quality production ✓ The state of technical infrastructure (degree of devices` wear) ✓ Reliability of devices ✓ Technical innovation	✓ Installing the capital-intensive machinery forces to maximize their use (capital investment) ✓ Time implementation of new solutions ✓ Repair cost and maintenance ✓ Cost of purifying and waste disposal ✓ Required permits for production and wastes	✓ Energy intensity ✓ Use of toxic materials ✓ VOC, dust emissions ✓ Noise/Odour/Radiation ✓ Solid/liquid wastes ✓ Transport	✓ Health & Safety at work, especially in the workplace hazardous to the health or life of man ✓ Knowledge and skills, competences of employees (employees training) ✓ Job performance and attitudes of employees ✓ Ergonomics ✓ Improvement of enterprise`s image by participating at community programmes

Source: Own based on empirical research
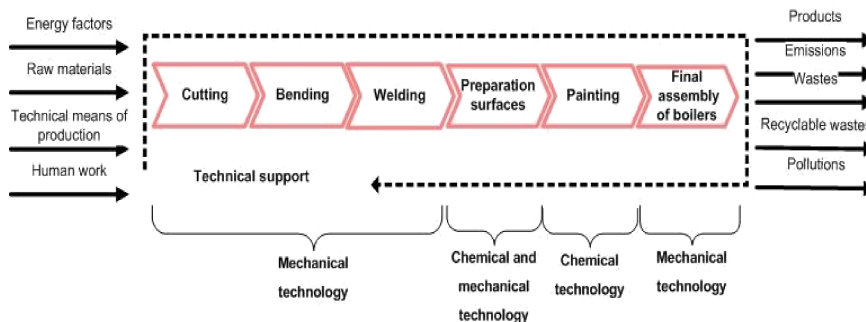
Fig. 1. Manufacturing processes for central heating boilers. Source: Own based on empirical research.

The indicator of influence I_{av} was calculated for two groups of manufacturing techniques: before and after their improvement as an arithmetic means from the sum of the partial results called the indicator of partial influence (I_{ij}) for processes (cutting, welding, bending, cleaning, painting and final assembly). Percent values of the indicator of the influence was defined as a calculation of the final impact index taking into account the economical, technological, social and environmental aspects divided by maximum possible to achieve scoring. The difference in scoring between two groups of the manufacturing techniques: before and after their improvement multiplied by 100 gives the percent value of the indicator's influence.

In the analysis of the manufacturing techniques, the cleaning and painting process had the greatest impact on the sustainable development of the enterprise. As a result, there was an improvement of 24% compared to the state of prior improvements. Somewhat less streamlining of (23%) was observed in the painting process. In regards to cutting and welding process it was a streamlining of 11% and 12% respectively (as shown in Fig. 2).

The analysis of the enterprise's manufacturing processes (base scenario) showed that the influence of manufacturing techniques on its sustainability is not strong and it is needed to find various ways of improving its manufacturing processes in order to prove the influence of these streamlines on the sustainable development of the enterprises. An in-depth study and a thorough investigation should be made before making decisions regarding the improvement of manufacturing processes and equipment selection for an application. Based on these findings, solutions were proposed in manufacturing processes relaying on making the improvement in processes or replacing the older model machines by more advanced ones (Table 2).
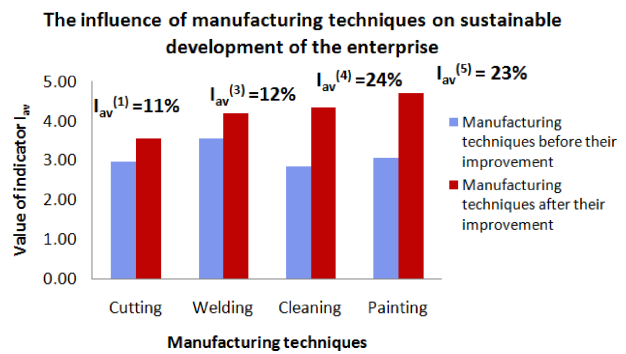

Fig. 2. Percent values of the influence indicator I_{av} of manufacturing techniques on sustainable development of the enterprise before and after their improvement. Source: Own based on empirical research.

Table 2
State of techniques for the base scenario and improvements scenario).

Manufacturing techniques	Existing techniques (base scenario)	Proposed solutions (improvement scenario)
Cutting	Steel sheets for boilers are cut in plasma (Jantar 2HD type by Eckert) by using a computer control system which accurately reproduces the shapes designed in CAD/CAM system. This technique enables cutting arbitrary, complex elements which do not require further finishing.	Laser cutting machine, workplaces to laser and plasma cutting will be equipped with a separation ventilation system (filtering system).
Welding	Welding of the boilers body with semi – automatic welding MIG/MAG in the shield of CO_2. SpG3S-wire electrode with a diameter of ϕ 1.2 mm Due to the high versatility of the process, MIG/MAG welding allows performing a variety of structures with different metals and alloys in the workshop and assembly conditions, in all positions. The burner is cooled with ethylene glycol. Welding stations are equipped with jigs and fixtures, lifts point.	Push – Pull welding ventilation system. Stationary and central suction and filtering systems with cartridge filter units reducing welding fumes and gases.
Cleaning	The whole process of applying color is preceded by thorough cleaning of the painted element: sanding, sometimes degreasing.	The abrasive blast processing with a closed abrasive circuit. For blasting the surface prior to welding it was intended to apply a dust-free, shot blasting machines suspending with shot closed circuit.
Wet painting	The paint coating on the base of solvent with the spraying hydrodynamic and air – operated method. Preparing the surface allows for permanent corrosion protection of the details.	Wet painting in spray booth. The use of paint spraying and drying cabin with air recirculation loop; with application technique of hydrodynamic spraying

Source: Own based empirical research.

The indicators of influence I_{av} for cleaning amount to $I_{av} = 4.19$ and for painting process $I_{av} = 4.33$, what compared with those activity areas for manufacturing processes before their improvement ($I_{av} = 2.72$, $I_{av} = 3.03$) have obtained a higher impact. For welding the value of indicator I_{av} stands at 3.91 after its improvement versus 3.32 before improvements have been implemented.

Partial parameters such as environmental, technical, economic and social ones have also improved (Fig. 3 versus Fig. 4). For cleaning process the highest mean value of indicator (I_{ENV}) stands at 0.51 versus 0.23 before improvement of the processes, while I_{SOC} amounts to 0.58 vs. 0.44.
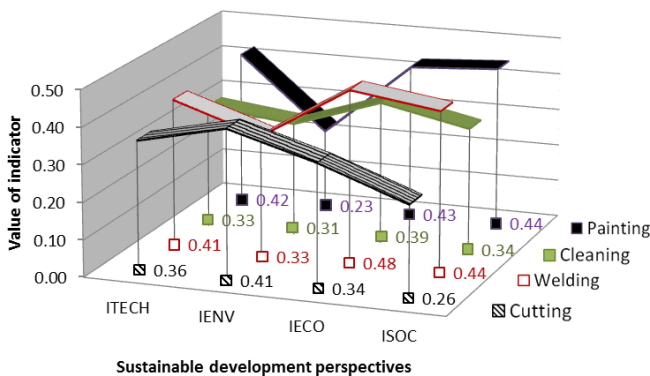
Fig. 3. Mean values of sustainable development perspectives for manufacturing techniques before their improvement. Source: Own based on empirical research.
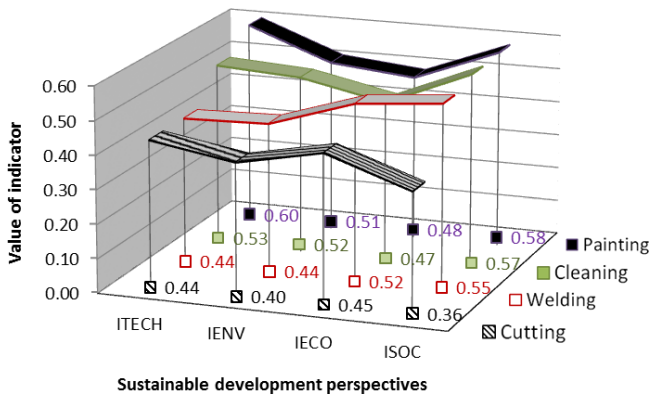

Fig. 4. Mean values of sustainable development perspectives for manufacturing techniques after their improvement. Source: Own based on empirical research.

Similar situation occurs in the case of painting process, where a mean value of influence $I_{ENV} = 0.52$ for manufacturing techniques after their improvement is high compared with a mean value of influence $I_{ENV} = 0.31$ before their improvement. A little bit higher value then previous one has the indicator $I_{SOC} = 0.34$ vs. $I_{SOC} = 0.57$ after the introduction

of improvement in the painting process. From the economical perspective, an increase in the values of indicator I_{ECO} is not pertinent due to investment in installation. It can be summarized that the economical dimension does not necessarily disagree with sustainable manufacturing, because if enterprises plan to increase the production volume, then it does not save energy (and materials too), especially advanced techniques require to be powered by electricity It highlights of how the enterprise social-environmental performance is strongly associated with financial and technological aspects of the enterprise.

It should be noted that enterprises produced heating devices boilers which are not able to reduce their impact in 100% on the environmental degradation. A positive phenomenon can be observed that due to the improvement of the existing cleaning and painting techniques the analyzed enterprise limits the impact of production processes on the environment well below current limits (i.e. welding, cleaning and painting process). The enterprise limits the amount of wastes and decreases the use of solvents needed to the production, improves the work conditions of its employees. In this way, the enterprise contributes to reducing the impact of industry on the surrounding natural environment.

Findings

Heating devices industry, especially manufacturing processes: welding, cleaning and painting are/have always been considered to be a source of the environmental problems. However, the industry is an important contributor to development. The need for achievement of the environmental improvements has been expressed by BAT and Cleaner Production as tools of the sustainable development in "green production" of boilers. The need for this approach is particularly essential in small and medium-sized enterprises whose cumulative impact on the environment and human health is often greater than that of large-scale incidents. The meaning of the new manufacturing techniques and technologies requires a continuous development and improvement of how the manufacturing processes are developed and assessed. This paper was done taking one of the manufacturing enterprise as a case study. The study was depicted and assessed in a medium-sized enterprise. Although this study is confined to a relatively narrow sample, arguably it is among those which are the most influential in achieving the sustainable development. It has been suggested in order to improve the processes and thereby minimize the waste generation. The right choice and use of welding, cleaning and painting

techniques in a way that ensures the maximum protection of the environment is one of the most important principles of the sustainable development. Under this policy, techniques aimed at reducing harmful effects on the environment, minimizing wastes and the emission of substances and gases into the air and soil has been recognized.

It was also observed there was an improvement of cleaning process of 24%. Somewhat less improvement was observed in the painting process of (23%). In regards to a cutting and welding process it was a streamlining of 11% and of 12% respectively. It shows a great importance of the influences on the sustainable development of the enterprise in cleaning and paint technique over the second ones. Results showed that improvement techniques and technologies presents potential for reducing environmental impacts and improve economic results in comparison to the base scenario for manufacturing techniques before their improvement. However, such applied options may not completely mitigate the environmental problems.

Results indicated that scenario for manufacturing techniques after their improvement in the considered plant is more suitable than the conventional ones (before their improvement).

In addition, it provided a substantial (economical and environmental) benefits of the improvement techniques, which are not equally available to all the heating devices businesses. The results of cost- benefit analysis have not been covered by this paper. Further, it allowed understanding of the real benefits of the enterprise flexibility in the Polish condition. In this context, improving environmental performance may require more financial outcomes to use new methods, technologies or alternatives not always leading to financial profits or return.

Speaking about cleaning and painting technology it will require changes not only in its technology but also in the way materials resources are supplied and the way there are used. If sustainable development is to be achieved, production process of heating boilers, has to be reoriented towards new patterns in order to reduce the environmental burden and bring better industrial productivity. The described application of the proposed solutions from the heating devices industry proves that sustainability is requiring improvement of manufacturing unit processes.

The presented assessment methodology that enables to assess the current state of manufacturing techniques is a value concept providing industrial companies the computation of sustainability performance. Therefore, it will facilitate a practical implication of this method.

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VERSITA ᛒmper

REDUCING TIME LOSSES IN OPERATIONAL ACTIONS OF A FOOD PRODUCTION LINES

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ABSTRACT
Most of the companies are interested in developing their production processes. With production process development, companies can meet their customers demands better. Tight competition is one reason that forces companies to use their production equipment as efficiently as they can. Improved production processes result in cost savings, flexibility, and in opportunities to plan companies activities more efficiently. The purpose of this research is to examine and cut operational times in food production processes. Two production lines were chosen for closer examination: spread/butter production line and quark production line. The main focus was to prevent operational time losses in these production lines. Research is divided into two separate sections: theoretical and empirical part. Theoretical part formulates guidelines and theoretical basis which is then employed in the empirical part. The theoretical part discusses Lean management philosophy, OEE indicator, SMED and questionnaire research method that comes from the sense and respond theory. In the empirical section, SMED and questionnaire method are used to examine operational activities. The focus is in finding critical characteristics from the production line's starting-, product change-, and closing-setups. Result was that certain characteristics can be found to be critical factors. Those characteristics are connected to operational time losses. Another result is, that SMED and questionnaire research method are an effective way to examine issues with production. Both methods produced similar results in finding development targets from the production line, hence the simultaneous use of both is beneficial, as additional confirmation for the first methods findings can be obtained by securing the result with the other one.

KEYWORDS
process development, operational times, sense and respond, SMED, OEE.

Introduction

Process development is very crucial part of the companies focus areas. Making more products with same resources is a goal that many companies are aiming at. Never ending process development is ensuring that company is maintaining its competitiveness in the markets. It also makes easier to gain new customers, which benefits company and its owners. When we are researching production processes, we can find important parts and attributes that can lead to significant results. Making these parts more efficient would affect to the whole production process positively. Companies that are operating in industrial markets are usually making their own products. Production plants are forming from many complicated processes. They are always transforming raw materials into some kind of products. Whole production can be divided into production lines that are responsible for transforming process. Production lines are using factors of production to make end products. Key point is that these processes should run as smooth as possible.

Transformation process should be as quick as it can get. This way money is tied to the production as little as possible. Ruling these processes efficiently should form basic ground to the business success.

This research was conducted in a food company called Valio Ltd. Valio ltd is a Finnish food company that is owned by Finnish dairy farmers. Research problem is very interesting: How can we decrease operational times so that we could achieve as much as possible productive production time? Research was focused on two different production lines. First line is making spread/butter type products and the other one is making quark products. Production lines are containing products making process, packing process, packing products to wholesale packages, and forming whole product pallets. Research was focused to these specific parts of the lines. Process parts that were handling/producing raw-materials and storage of end products were ruled out.

Literature Review

Single Minute Exchange of Die (SMED)

Customers are demanding fast delivery and reliable delivering schedule. For meeting these requirements, companies are forced to organize their production in a way that product passing times should be as fast as it can get. Another option could be stocking products, but then money would be bound to the stocks. Lean management has drive companies to cut down all necessities. Production flexibility can be seen in product batches. Companies should focus to small batches because then they can react to customer demands better and drive their production to make to order system. Smaller batches are leading to more changeovers in production. That is a reason for companies to improve their actions in batch changeovers [1].

SMED was created to improve setup changes and to cut production time losses. SMED is known for being powerful lean management method. It was originally created in Toyota motor company production plant, by consultant named Shigeo Shingo. The goal was that every changeover could be done less the 10 minutes, hence the name SMED (Single minute exchange of die) [2]. We must remember that the ultimate goal would be changeover that will give result as a zero. Time loss would be zero minutes. These kinds of changes are named One Touch Setups, push one button and the setup is done [3]. SMED can be applied easily to many different kind of production lines. Ideas, that this method brings, are very easy to adapt to any kind of setups. Many of them are concerning human behavior and a way how people are handling changeovers. Usually there are no investments required, at least in the beginning of improvement process.

Three steps model

SMED method is implemented with three different steps [2, 3]. All these steps are very easily to follow, but it requires patience, because examined information must be gathered very precisely. Steps:

1. **Dividing setup works to internal and external setups.** First step is to follow the whole setup from start to end. Every operation and movement should be written down, measure how long it will last and it should be divided to internal or external operation. Internal operation is something that is done when the production machine is shut down. External operation is done when the machine is still operating. For example new materials are fetched near to machine, while it is still operating old materials. At the same time information can be analyzed so that the preliminary decisions can be made which internal operations could be transformed into external operations. Same setup should be monitored many times and with different people doing setups. This way SMED can reveal best practices to manage the changeovers.

2. **Internal operations are transformed to external operations.** In this stage all the possible internal operations should be transformed into external operations.

3. **Make changeover as lean as it can get.** Improve all remaining internal operations. Operations should be done parallel way and automatic adjustments, models, templates, and special tools should be used as much as possible. Unnecessary movements and wrong work habits should be root out in this stage.

Target is to create standard for proper changeover that every operator would use. Approximately SMED can reduce time in changeover 80–95% from the original time [4].

Overall Equipment Effectiveness (OEE)

OEE is key measurement indicator in Lean production. It indicates how efficiently production is producing a product that meets the quality requirements [5]. OEE is counting production lines efficiency by three different sectors. These sectors are:

- Availability %,
- Speed %,
- Quality %.

OEE is revealing the state of the production. For example if production line is available 80% of time, it operates at 80% of speed and the quality rate is 80% then the OEE Number is only 51%.

Sense and respond

Sense and respond – methodology has been invented by Stephan H. Haeckel. Method is offering tools to handle futures uncertainties. Sense and respond – organization is trying to sense customer needs and business opportunities when they occur. It's not focused to reveal future incomes. Reacting to signals as fast and correctly as possible, before they are weakened or changed, is a top priority [6].

Fast development of information technology has affected many companies to change their make to sell system to sense and respond system. Make and sell systems are losing it's battle to sense and respond systems because system that is based on a budget and history knowledge isn't match for quick and adaptive system like sense and respond. Best case scenario is that system can predict customer expectations that haven't even occurred yet. Final solution to operation system is an outcome that can find critical resources to satisfied customer demand. And execution is efficient [7].

Sense and respond – model has been target to active development past years. Based on this original theory Rautiainen and Takala [8] have developed questionnaire method that can reveal customer satisfaction and point out critical resources or attributes from the system. This method can be implemented to internal and external organizational attributes. It is considering attributes development in past and it is predicting the attributes future development. Original idea for this questionnaire is to develop a quick and reliable way to find out customer needs and to react to these needs so that the right attributes are developing. It is also easy and quick way to gather information.

Questionnaire

Questionnaire is formed from attributes that are relevant and crucial to research. Each attribute must be very close to research problem. Questionnaire was formed same way as it is in Fig. 1. Original questionnaire was modified because it contained part that was asking respondent opinion about competitors processes. We can assume that process workers aren't familiar with competitors processes. Respondents are assessing attributes by expectations and experiences with numbers. Direction of development, past and future, is assessed by choice of worse, same, or better. Questionnaire has an open space that respondent can write more information, if needed. Table 1 is indicating what kind of attributes was used in this research.

Gathered information is analyzed by ten different index: average of expectations, average of expe-

riences, importance index, performance index, Gap index, direction of development past, direction of development future, critical factor index (CFI), balanced critical factor index (BCFI) and scaled critical factor index (SCFI).

Fig. 1. Model of the questionnaire [8] (modified).

Table 1
Questionnary attributes.

Start setup	
Attribute 1	Availability of materials/raw materials
Attribute 2	Proper tools
Attribute 3	Quality issues
Attribute 4	Work help
Attribute 5	Other teams waiting
Attribute 6	Information flow
Changeover setup	
Attribute 7	Availability of materials/raw materials
Attribute 8	Proper tools
Attribute 9	Production schedule
Attribute 10	Quality issues after changeover
Attribute 11	Waiting for the previous process
Attribute 12	Waiting for the after process
Attribute 13	Availability of changed parts
Attribute 14	Work help
Attribute 15	Work instructions in changeover
Attribute 16	Information flow related to changeover
Ending setup	
Attribute 17	Proper tools
Attribute 18	Quality issues
Attribute 19	Work help
Attribute 20	Other teams waiting
Attribute 21	Information flow

Fig. 2. Gap, direction of development, important, avg. of experience, avg. expectation, and CFI indexes [9].

When gathered information is calculated by these indexes we can proceed to find critical attributes.

Gap analysis (1) is used to compare differences between customers expectations and experiences. With this basic tool, those attributes where the experiences were more insignificant than expectations, can be identified [10]. Direction of development (2) is revealing the direction of each attributes development in past and future tenses. Important index (3) and performance index (5) are very close to each others. Both (Important index and performance index) are calculated by taking expectation or experiences number and then dividing it by the number ten. Most important indexes are the critical factor indexes (4). These indexes are revealing attributes that can be named critical. Critical attribute is an attribute that will increase total productivity of a process. Adding more resources to critical attribute will make the existing process run more smoothly and efficiently. Critical index (CFI, BCFI (5), and SCFI (7)) is also revealing attributes that are already in a good level of performance. If we add more resources into these attributes, we don't increase process overall efficiency. BCFI index is a basically same index as CFI but it has been weighted by performance index NCFI (6) index will reveal the SCFI index when it is calculated to every attribute and the divided with it's own sum. SCFI index has been created to solve problems that are occurred when respondent sample is too narrow. For working properly, critical indexes need 3 or more respondents.

$$(5) \quad BCFI = \frac{\text{SD of expections x SD of experience x performance index}}{\text{Importance index x Gap index x direction of development index}}$$

$$(6) \quad NCFI = \frac{\sqrt{\frac{1}{n}\times\sum_{i=1}^{n}\left(\text{Experience}\right)(i)-1)^2}\sqrt{\frac{1}{n}\times\sum_{i=1}^{n}\left(\text{Expectation}\right)(i)-1)^2}}{\text{Gap index x direction of development index x Importance index}}$$

$$(7) \quad SCFI = \frac{NCFI}{\sum NCFI}$$

Fig. 3. BCFI, NCFI and SCFI index [11, 12].

Research empirical part

SMED analysis

SMED method was used to research same start, changeover, and ending setups as in the questionnaire method. Research was conducted as the theory insisted by three stages. All production processes (product producing, 1 area packaging and 2 area packaging) were investigated. Totally amount of SMED research was 22 monitoring in spread department and 20 in quark department. Focus was in bottlenecks that were revealed during the study. Every monitoring produced a table were we can see how the investigated work phase was created. After creating table, like Table 2, we could accurately create another table where all the possible internal works could be moved to external work.

Table 2
SMED table of 1 area packaging machine changeover in spread department.

Work phase	Time	Internal	External
Upper interleaf bowl out	20		x
Production ending	40	x	
Cases out from the conveyor belt	40	x	
Lids out of the magazine	45	x	
Extra lids out of the machine	105	x	
Extra cases out of the machine	55	x	
Taking cases+interleaf out and fech new ones	125	x	
Taking lids out and fech new ones	235	x	
Zeroing counter	5	x	
Loading setup + change packaking size	15	x	
Stages 1 to 3	35	x	
Feching the part car	45	x	
Changing interlefs to lower bowls	100	x	
Changing interlefs to upper bowls	35	x	
Change of lid grabers	105	x	
Stages 5-7	40	x	
Change of case jig	70	x	
Stages 9-10	30	x	
Change of case plate	85	x	
OEE + product number	40	x	
Old packaking materils out from the inside of machine	50	x	
Starting cases into the machine	70	x	
Cases to the magazine	295	x	
Lids to the magazine	345	x	
Change of weight system	85	x	
taking out the part car	30	x	
Starting the production	170	x	
Work stage: Grunwald 600 g was changed to 400 g. 2 person did the job. Started 9:28 Ended 9:57 29 min	2315	27	1
Internal time	38 min 5 s		
External time	20 s		
Time total	38 min 25 s		

Table 3
SMED table of 1 area packaging machine changeover in spread department, corrected.

Work phase	Time	Internal	External
Upper interleaf bowl out	20		x
Production ending	40	x	
Cases out from the conveyor belt	40		x
Lids out of the magazine	45		x
Extra lids out of the machine	105		x
Extra cases out of the machine	55		x
Taking cases+interleaf out and fech new ones	125		x
Taking lids out and fech new ones	235		x
Zeroing counter	5	x	
Loading setup + change packaking size	15	x	
Stages 1 to 3	35	x	
Feching the part car	45		x
Changing interlefs to lower bowls	100	x	
Changing interlefs to upper bowls	35		x
Change of lid grabers	105	x	
Stages 5-7	40	x	
Change of case jig	70		x
Stages 9-10	30	x	
Change of case plate	85	x	
OEE + product number	40	x	
Old packaking materils out from the inside of mac	50		x
Starting cases into the machine	70		x
Cases to the magazine	295		x
Lids to the magazine	345		x
Change of weight system	85	x	
taking out the part car	30		x
Starting the production	170	x	
Work stage: Grunwald 600 g was changed to 400 g. 2 person did the job. Started 9:28 Ended 9:57 29 min	2315	12	15
Internal time	12 min 30 s		
External time	26 min 5 s		
Time total	38 min 25 s		
Internal time less	25 min 35 s		

Table 4
SMED table of 1 area packaging machine changeover in quark department.

Work phase	Time	Internal	External
Fetching new packaking materials + inserting materials into machine	180		x
End the product insert + end the production	50	x	
Zeroing counter + OEE	35	x	
Extra cases out of the machine	60	x	
Starting cases into the machine	70	x	
Taking off dosing tubes	105	x	
Dosing tubes pre-wash	50	x	
Activate cleanin-in-progres	75	x	
Changing pipe root	15	x	
Machine CIP	2400	x	
Taking off interleafs from the bowl	225		x
Change the production date marks	39		x
Change of interleaf takers	140		x
Takeing old materials away	120		x
CIP off	92	x	
Inserting the dosing tubes	180	x	
Asking product producers to start production	180	x	
Filling up the product bin	95	x	
product circulate	175	x	
Cleaning the product tubes	60	x	
Starting the production	420	x	
Work phase: Grunwald changeover 9.11.11. 2 person did the job. Started 15:45 Ended 16:55	4766	16	5
Internal time	1 h 7 min 42 s		
External time	11 min 44 s		

Table 5

SMED table of 1 area packaging machine changeover in quark department, corrected.

Work phase	Time	Internal	External
Fetching new packaking materials + inserting materials into machine	180		x
End the product insert + end the production	50	x	
Zeroing counter + OEE	**35**		x
Extra cases out of the machine	**60**		x
Starting cases into the machine	**70**		x
Taking off dosing tubes	105	x	
Dosing tubes pre-wash	**50**		x
Activate cleanin-in-progres	75	x	
Changing pipe root	15	x	
Machine CIP	2400	x	
Taking off interleafs from the bowl	225		x
Change the production date marks	39		x
Change of interleaf takers	140		x
Takeing old materials away	120		x
CIP off	92	x	
Inserting the dosing tubes	180	x	
Asking product producers to start production	**180**		x
Filling up the product bin	95	x	
product circulate	175	x	
Cleaning the product tubes	60	x	
Starting the production	420	x	
Work phase: Grunwald changeover 9.11.11. 2 person did the job. Started 15:45 Ended 16:55	4766	11	10
Internal time	1 h 1 min 7 s		
External time	18 min 19 s		
Time total	1 h 19 min 26 s		
Internal time less	6 min 35 s		

In Table 3 we can see how process part could be improved. All the bolded work phases could be transformed into external phases. In this specific case internal time would be 25 minutes shorter then before. This would increase productive production time quite a lot. In Tables 4 and 5 we have monitored similar situation, but in quark department.

In quark department all monitored SMED situations were a bit more difficult to transform. It was clear that in this department production efficiency improvement had already been in under the surveillance. There were only few things that could be improved and this was the situation in almost all the cases. Last step was to improve internal work phases as much as possible.

Information was gathered by questionnaire which was specially designed to investigate these operational times. Four different personnel groups were selected to answer this questionnaire: product producers, 1 area packers, 2 area packers, and process supervisors.

When we are focusing on a specific problem like this we should investigate these production processes precisely. This is the main reason for these 21 attributes that are used in this research. All attributes are related to start, changeover, and ending setups. 30 people respond to the questionnaire, 17 from the spread production line and 13 from the quark line. Respond percent was 81. Three or more responds were received per personnel group, but the process supervisors from the quark line gave only two responds. This is a bit problematic because in order to achieve dispersion, three or more replays should be collected. This is the reason why SCFI index was calculated in first place.

Tables 6 and 7 are showing preliminary results of spread and quark lines which are analyzed by indexes that are introduced in this research.

We can notice that all the attribute experience averages are smaller then the expectations in both production lines. Still the level of grades is in good stages at both lines. Standard deviation is considered to be high on some attributes, but if the SD of an attribute is high on expectations it will be lower in the experience category. Gap index is showing how experiences have lower numbers then the expectations. If the gap number is big then the gap between experience and expectation is wide. Small number in development index is indicating that the attribute has developed well.

Table 6
Preliminary result for answers collected from spread department.

	Average of expectation	SD Expectation	Average of experience	SD Experience	Gap index	Development index past	Development index future
Attribute 1	9.21	0.41	8.17	0.78	1.13	0.77	0.77
Attribute 2	9.19	0.65	8.34	0.67	1.11	**0.47**	0.77
Attribute 3	9.19	0.59	7.74	0.62	1.18	1.00	**0.47**
Attribute 4	8.11	1.42	7.54	**1.46**	1.07	1.00	1.00
Attribute 5	7.46	1.36	6.53	0.86	1.12	1.30	0.77
Attribute 6	8.71	0.76	6.66	1.09	**1.26**	1.23	0.85
Attribute 7	**9.30**	0.47	**8.65**	0.30	1.08	0.77	0.77
Attribute 8	9.05	0.79	**8.58**	0.42	1.06	**0.40**	0.77
Attribute 9	**9.40**	0.48	6.53	0.91	**1.36**	1.08	0.92
Attribute 10	**9.30**	0.59	8.05	0.27	1.16	0.92	0.62
Attribute 11	8.02	1.59	7.83	0.59	1.02	0.85	0.62
Attribute 12	8.09	**1.65**	7.27	0.55	1.10	0.92	**0.55**
Attribute 13	9.19	0.91	8.54	0.58	1.08	0.62	0.92
Attribute 14	8.24	1.09	7.48	**1.44**	1.10	1.08	0.92
Attribute 15	9.16	0.82	8.00	1.06	1.15	0.77	0.62
Attribute 16	8.84	1.09	6.78	1.28	**1.26**	1.23	0.62
Attribute 17	8.90	0.97	8.52	0.39	1.05	0.70	0.70
Attribute 18	9.06	0.93	8.11	0.37	1.12	1.00	0.77
Attribute 19	8.11	1.05	7.58	1.42	1.07	1.08	1.08
Attribute 20	7.88	**1.64**	7.11	0.98	1.10	1.00	0.77
Attribute 21	8.75	1.36	7.05	1.35	1.21	1.30	0.77

Table 7
Preliminary result for answers collected from quark department.

	Average of expectation	SD Expectation	Average of experience	SD Experience	Gap index	Development index past	Development index future
Attribute 1	8.88	0.55	8.24	0.48	1.08	**0.67**	0.67
Attribute 2	8.83	1.38	7.98	**1.62**	1.11	**0.67**	0.33
Attribute 3	**9.40**	0.43	8.06	0.90	1.17	**0.67**	0.67
Attribute 4	8.94	0.25	6.96	0.51	**1.25**	1.00	0.67
Attribute 5	9.11	0.31	7.46	0.98	1.21	0.75	0.67
Attribute 6	8.08	**2.10**	6.67	1.30	1.18	1.00	1.00
Attribute 7	9.15	0.23	8.15	0.19	1.13	**0.67**	1.00
Attribute 8	9.15	0.23	8.20	0.18	1.12	**0.42**	0.67
Attribute 9	9.20	0.40	7.24	1.24	**1.25**	1.00	0.33
Attribute 10	**9.53**	0.25	8.07	0.30	1.18	**0.67**	0.67
Attribute 11	7.58	**1.75**	6.87	0.67	1.09	1.08	**0.33**
Attribute 12	8.50	0.48	7.55	0.48	1.12	0.92	**0.33**
Attribute 13	8.52	1.41	7.59	0.97	1.12	1.00	0.67
Attribute 14	8.85	1.20	6.89	0.70	**1.25**	1.00	0.67
Attribute 15	9.35	0.10	8.29	1.03	1.13	0.75	0.67
Attribute 16	8.60	**1.75**	6.99	**1.67**	1.20	1.08	0.67
Attribute 17	9.10	0.43	**8.47**	0.47	1.08	0.75	0.67
Attribute 18	9.25	0.15	**8.55**	0.56	1.09	0.83	1.00
Attribute 19	8.79	0.77	6.72	1.07	**1.26**	1.00	1.00
Attribute 20	8.69	0.70	7.75	0.51	1.12	0.83	0.67
Attribute 21	8.48	1.67	6.76	1.61	1.21	0.92	0.33

Critical indexes can be found in the Tables 8 and 9. All factors have been analyzed by past and future development index. Indexes are formed from the numbers that have been calculated together from each personnel group.

CFI and BCFI index solutions should be monitored with a hint of skepticism, because there weren't enough answers to create acceptable level of confidence due to poor level of standard deviation. SC-FI index proved to be the key index in this research. Critical factors that were found out by this index were attributes that matched with the problems and development targets of both production lines.

Table 8
Preliminary result for critical indexes (CFI and BCFI) from the spread and quark department.

	CFI past spread	CFI past quark	CFI future spread	CFI future quark	BCFI past spread	BCFI past quark	BCFI future	BCFI future
Attribute 1	**0.014**	0.010	**0.010**	0.008	**0.015**	0.012	**0.012**	0.010
Attribute 2	0.132	0.165	0.015	0.079	0.153	0.165	0.019	0.082
Attribute 3	0.036	0.017	0.103	0.051	0.036	0.019	0.114	0.054
Attribute 4	0.084	0.076	0.056	0.029	0.080	0.074	0.058	0.031
Attribute 5	0.062	**0.008**	0.092	**0.007**	0.046	**0.008**	0.072	**0.008**
Attribute 6	0.030	0.090	0.034	0.130	0.024	0.070	0.028	0.103
Attribute 7	**0.017**	0.022	**0.012**	0.012	0.020	0.026	0.016	0.014
Attribute 8	0.087	0.046	0.024	0.014	0.102	0.057	0.031	0.016
Attribute 9	0.024	0.038	0.016	0.035	0.023	0.039	**0.012**	0.036
Attribute 10	0.023	0.020	0.020	0.018	0.024	0.020	0.023	0.020
Attribute 11	0.075	0.100	0.056	0.118	0.090	0.095	0.074	0.116
Attribute 12	0.034	**0.007**	0.071	0.010	0.030	**0.008**	0.069	0.011
Attribute 13	0.033	0.067	0.022	0.094	0.039	0.079	0.029	0.113
Attribute 14	0.059	0.126	0.056	0.106	0.054	0.122	0.055	0.105
Attribute 15	0.054	0.018	0.054	0.015	0.053	0.021	0.056	0.018
Attribute 16	0.021	0.071	0.054	0.137	**0.015**	0.062	0.041	0.123
Attribute 17	0.029	**0.006**	0.046	**0.005**	0.033	**0.007**	0.061	**0.007**
Attribute 18	0.028	0.011	0.025	0.014	0.030	0.014	0.032	0.017
Attribute 19	0.054	0.093	0.049	0.076	0.050	0.086	0.047	0.072
Attribute 20	0.062	0.033	0.121	0.040	0.049	0.035	0.100	0.044
Attribute 21	0.044	0.074	0.065	0.141	0.032	0.059	0.051	0.114

Table 9
Preliminary result for SCFI index from the spread line, all personnel groups.

SCFI	product producers		1 area packers		2 area packers		process supervisors	
	past	future	past	future	past	future	past	future
Attribute 1	0.066	0.040	0.042	0.040	0.051	0.036	0.026	0.039
Attribute 2	0.323	0.048	0.051	0.037	0.087	0.035	0.049	0.043
Attribute 3	0.058	0.035	0.030	0.248	0.026	0.050	0.025	0.155
Attribute 4	0.041	0.034	0.050	0.026	0.042	0.060	**0.016**	0.018
Attribute 5	**0.020**	0.056	0.032	0.038	0.024	**0.032**	0.020	0.024
Attribute 6	0.020	0.040	**0.019**	0.016	**0.021**	0.070	0.023	**0.014**
Attribute 7	0.069	0.042	0.059	0.043	0.039	0.040	0.029	0.044
Attribute 8	0.072	0.063	0.085	0.030	0.106	0.043	0.208	0.044
Attribute 9	**0.014**	**0.021**	**0.016**	**0.015**	0.019	0.047	0.194	**0.016**
Attribute 10	0.021	0.060	0.069	0.035	0.034	0.050	0.025	0.038
Attribute 11	0.029	0.063	0.117	0.060	0.037	0.053	0.029	0.044
Attribute 12	0.035	0.053	0.043	0.071	0.034	0.087	0.031	0.027
Attribute 13	0.042	0.045	0.059	0.043	0.091	0.037	0.052	0.018
Attribute 14	0.028	0.042	0.028	0.023	0.058	0.058	0.021	0.018
Attribute 15	0.021	0.061	0.055	0.050	0.056	0.057	0.050	0.024
Attribute 16	0.022	0.061	0.022	0.045	0.024	0.035	**0.015**	0.019
Attribute 17	0.030	0.046	0.054	0.039	0.110	0.044	0.055	0.194
Attribute 18	**0.017**	**0.032**	0.080	0.029	0.027	0.050	0.048	0.166
Attribute 19	0.023	0.035	0.028	0.023	0.058	0.041	0.034	0.020
Attribute 20	0.029	0.063	0.036	0.061	0.034	**0.034**	0.031	0.019
Attribute 21	0.021	0.060	0.023	0.027	0.022	0.040	**0.017**	**0.015**

Preliminary analysis for all (spread department)

We can see that there are four major critical attributes. Attributes 6 and 21 are related to the communication between different personnel groups in start and ending setup. Attribute 9 (production schedule) is the clearest critical factor. Also attribute 18 (quality issues in ending works) is critical. Highest numbers were given to a tools that are needed in changeover and ending work.

Preliminary analysis, product producers (spread department)

Critical factors are attributes 5, 8, and 18 when measured in past. Waiting for other parts of the process in start works (5), production schedule (9), and quality issues in ending works (18) should be improved if we wanted to increase our productivity from the product producers point of view. When estimated these attributes with future aspect same critical factors emerge. Only other team waiting is turned into the green zone. Attributes 2, 8, 11, and 20 is considered to be in a good level or level that should be investigated more precisely.

Preliminary analysis, 1 area packers (spread department)

1 area packers are considering production schedule (9) and information flow in start work (6) to be critical factors. Both critical attributes are also critical if we look SCFI index by the view of future tense. Best attributes are proper tools (8) and previous process waiting in changeovers (11). In the future best attributes will be quality issues in start setup (3) and previous process waiting in the changeovers (12).

Preliminary analysis, 2 area packers (spread department)

2 area packers feel that critical factor should be almost same as what 1 area packers have chosen. In the past attributes 6 and 9. In the future tense critical factors are different. Other teams waiting in start (5) and ending works (20) is considered to be critical. Highest score was given to attributes that are related to tools and parts that are changed in changeover setups (8, 13, and 17). Information flow in start setup (6) and waiting for the after process in changeover setup (12) is voted for the best candidates in future. We should notice that the critical attribute, information flow in start setups, will change its state in the future tense to be almost best attribute. This is indicating that people are hoping a big change to this attribute.

Preliminary analysis, process supervisors (spread department)

Process supervisors have chosen few attributes to be critical factors: information flow in changeover (16), ending setups (21), and also work help in start setups (4). Attributes that will be critical in future are information flow in ending (21) and start setups (6), and also production schedule (9). Production schedule is very interesting attribute, because it is one of the best attributes in the past, but it will drop to critical in the future. Proper tools in changeover (8) have also received high qualification. Ending setup tools (17) have received major numbers at the future tense. Other attribute that had high value were quality issues at ending setups (18).

Table 10
Preliminary result for SCFI index from the quark line, all personnel groups.

SCFI	product producers		1 area packers		2 area packers		process supervisors	
	past	future	past	future	past	future	past	future
Attribute 1	0.060	0.034	0.053	0.034	0.032	0.065	0.090	0.049
Attribute 2	0.064	0.036	0.050	0.047	0.049	0.033	0.048	0.081
Attribute 3	0.059	0.084	0.042	0.275	0.046	0.031	0.048	0.046
Attribute 4	0.045	0.051	**0.020**	**0.016**	0.155	0.045	**0.020**	0.035
Attribute 5	0.036	0.063	0.138	0.036	**0.017**	**0.019**	0.035	0.034
Attribute 6	**0.034**	0.069	0.054	0.025	**0.015**	0.033	0.033	0.031
Attribute 7	0.063	0.036	0.053	0.034	0.027	0.031	0.078	**0.030**
Attribute 8	0.105	**0.034**	0.048	0.077	0.231	0.038	0.078	0.043
Attribute 9	**0.020**	0.037	0.028	**0.022**	0.032	0.038	0.085	0.081
Attribute 10	0.045	0.091	0.055	0.063	0.041	**0.028**	0.049	0.047
Attribute 11	0.052	0.060	0.030	0.036	0.024	0.039	0.031	0.076
Attribute 12	0.041	**0.033**	0.056	0.052	0.027	0.055	0.031	0.076
Attribute 13	0.036	0.038	0.034	0.041	0.038	0.078	0.048	0.076
Attribute 14	0.043	0.049	**0.023**	**0.015**	0.051	0.060	**0.017**	0.030
Attribute 15	0.046	0.045	0.038	0.032	0.028	0.058	0.085	0.047
Attribute 16	0.038	0.044	0.026	0.032	**0.019**	0.056	0.031	0.042
Attribute 17	0.042	0.049	0.055	0.036	0.058	0.068	0.048	0.046
Attribute 18	0.044	0.036	0.082	0.053	0.022	0.064	0.045	0.030
Attribute 19	0.047	0.038	**0.022**	**0.014**	0.043	0.050	**0.017**	**0.021**
Attribute 20	0.044	0.035	0.052	0.034	0.030	0.061	0.042	0.040
Attribute 21	0.036	0.041	0.040	0.026	**0.017**	0.049	0.041	0.069

Preliminary analysis for all (quark department)

SCFI index is indicating that there are three critical attributes in the quark department. Availability of material/raw materials (1, 7) are attributes that are critical in future. Also work help in ending setups will be in critical phase. In past, information flow in changeovers and quality issues in start, are considered to be critical attributes.

Preliminary analysis, product producers (quark department)

Product producers have chosen product schedule (9) and information flow in start setup (6) to be critical. In future critical attributes will be waiting for the previous process (11) and proper tools (8) in changeover. Product producers are feeling that needed tools in changeover are in best shape at the past but they will be critical in future. Reason for this could be found from the level that tools have already achieved. High qualification is causing sinking in the future. Other attributes that rose up were tools in start setup (2), quality issues in start, and changeover setups (3, 10).

Preliminary analysis, 1 area packers (quark department)

1 area packers have chosen only one attribute to be critical. Work help (4, 14, and 19) in every part of start, changeover and ending setups. This attribute is critical in both tenses past and future. Clear message is indicating that more help is needed in the 1 area. Production schedule (9) will be also critical in future. In past, good attributes are other teams waiting in start setup (5) and quality issues in ending setup (18). In future critical factors will be quality issues (3) and proper tools (2) in start setup.

Preliminary analysis, 2 area packers (quark department)

Information flow (6, 16, and 21) is named to be critical attribute in every part of the process. In future 2 area thinks that all the information problems will be diminished to non-critical attributes. In future other teams waiting in start setup (5) and quality issues in changeover (10) has chosen to be critical. Work help in start setup (4) and proper tools in changeover (8) are in good side of the scale in past. In future parts that are needed in changeover (13)

and proper tools in ending setup (17) will be in good hands.

Preliminary analysis, process supervisors (quark department)

Work help (4, 14, 19) is critical in start, changeover and ending setups. Work help is also critical in future, but only in ending works. Other attribute that is lacking resources is availability of material/raw material in changeover (7). In the good side, there are availability of material/raw material in start setup (1) and work instructions in changeover (15). In future, there will be proper tools in start setup (2) and production schedule (9) that are in good stage.

Conclusions

In the long run all these changes should be effecting to production efficiency. Effectiveness can be monitored and measured by OEE. OEE should be increased from the availability part. Results, which were received from questionnaire method, were tested with semi-strong market test. In this test all results were verified with the help of operating personnel. Critical attributes were founded. Difference between CFI, BCFI, and SCFI indexes can be explained with the standard deviation and different weightings in the answers. SCFI index gave best results when critical factors were presented to the personnel. Also SMED method was giving results that specific attributes should be improved. And these attributes were the same critical factors what we got from the questionnaire analyze. Research is indicating that in order to get valid results, both methods should be used simultaneously.

Reliability of the research results can be stated to be correct. All information was gathered from the process with researchers own experience included. Monitoring the process was very crucial to the research. For the further development of these methods, information could be gathered for a longer time. This would improve results, because with more start, changeover, and end setups monitored material could be trusted more and then the personnels way of doing work phases could be monitored better. This would lead to findings for the best working habits.

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THE IMPLEMENTATION OF THE BALANCED CRITICAL FACTOR INDEX METHODOLOGY IN THE STRATEGY REDEVELOPMENT PROCESS

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ABSTRACT
Strategic planning and development is a critical yet often overlooked issue in company's operations. The planning of development as well as addressing the distribution of available resources should be done systematically rather than instinctively however, many companies still do not have any reliable method that would facilitate the decision making processes at their disposal.

This article aims at presenting the innovative analytical method- Balanced Critical Factor Index (BCFI) for addressing the need for change in company's operational strategy according to changes in available technology and knowledge. By examining a wide array of indexes, the presented method is expected to suggest the directions of development. The presented method also addresses the challenges of the complex process of decision-making. Moreover, the empirical evidence gathered in the studied case company serves as a source of important feedback regarding the further improvement of the BCFI method.

KEYWORDS
Balanced Critical Factor Index, decision-making, strategy.

Introduction

The careful crafting, development, implementation and ultimately redevelopment of a strategy are crucial elements of company's survival. Although such statement might seem trivial, many companies begin the process of strategy redevelopment only after they find themselves outstripped by competitors, facing no opportunities to grow. Moreover, according to [1] nearly 70 per cent of strategic plans and strategies are never successfully implemented. Companies might perceive the process of examining the existing strategy unnecessary and mundane, failing to see the connection between its elements and day-to-day operations. Nevertheless, nowadays turbulent environment and rapid information flow imposes the requirement of flexibility and high responsiveness. In

order to be able to accomplish the aforementioned, companies should be aware of their critical attributes, technologies as well as the resources that can be assigned to their development. According to [2] strategy is an ongoing process and a certain way of thinking of the whole business based on identification of strengths and weaknesses and the evaluation of opportunities. Therefore, strategy should be seen as an evolution rather than ad hoc activity.

According to [3] strategic decision making is a highly complex process that involves many different variables. The author outlines several characteristics that determine whether a decision is strategic or not. The criteria are as follows:

- Decisions regarding organization's relationships to its environment;
- The whole organization as a unit of analysis;

- Decisions encompassing all the major functions performed by the organization;
- Decisions providing constrained guidance for all of the administrative and operational activities of the organization;
- Critical importance for the long-term success of the organization.

The concept of strategic gap is also mentioned by [3]. The gap is bound with the fact that strategic decisions affect the organization's relationship with external environment. The concept illustrates the discrepancies between organization's current situation and external environment. In other words, it is the difference between where the organization is and where it wants to be. According to [3] the strategic gap can be determined by can be determined by comparing organization's capabilities with the opportunities and threats of the external environment. The author also emphasizes that the situation where there is no strategic gap is almost impossible. Therefore, the organizations should focus on minimizing the strategic gap by exploiting the opportunities while utilizing the internal capabilities as effectively as possible.

The decision-making process and its importance should be perceived through the wide array of its functions. The following were outlined by [3]:

- Determining strategic objectives;
- Exploring, comparing and evaluating alternatives;
- The final act of choosing from the variety of alternatives;
- The implementation of a chosen alternative;
- Controlling and monitoring the results of the decision made.

The functions of the decision-making highlight the complexity of the process. Moreover, in the context of limited time and information available combined with ever changing external business conditions, the importance of making the right decisions in the right time.

Turbulent environment requires quick decision-making processes and therefore this paper suggests the implementation of the Balanced Critical Factor (BCFI) analysis developed by [4]. The paper addresses the question whether the BCFI methodology fulfills the requirement imposed by the dynamic nature of strategy- the frequent monitoring of current situation as well as the awareness of those attributes that are crucial to organization's development. Moreover, by conducting the market-based validation (weak market test) developed by [5] the method is tested in terms of the suggested directions of development and therefore the formulas used for their calculation. The paper aims to contribute to the sci-

entific knowledge within the area of methodologies supporting the strategic decision-making process.

Balanced Critical Factor Index (BCFI) analysis

BCFI analysis was developed by Professor Josu Takala as an improvement to the previously proposed Critical Factor Index analysis. According to [4] both methods can be perceived as measurement tools that are intended to indicate which of the analyzed attributes are critical and which are not and therefore the model can be concerned a useful tool for strategic decision-making. The BCFI analysis has been successfully implemented in e.g. automotive industry [6, 7] or fine gold jewelry export [8].

The stimuli for developing a framework for facilitating the decision-making process and strategic development developed during the earlier empirical research in various companies. Identified was the need for a tool that would fulfill the following criteria:

- Understandable and relatively easy to use in practice;
- Providing valuable insight into company's situation in terms of a various dimensions;
- Providing directions regarding the strategic development in the future;
- Based on quantitative rather than qualitative data and quantified assessment.

The development of the BCFI was initiated in response to the aforementioned requirements. The method will be assessed in terms of being capable of addressing the requirements further in this paper.

The BCFI analysis utilizes the survey structure which, according to [4], is an efficient approach to reaching the desired response. The main challenge of the questionnaire creation is the selection of the attributes that would best represent company's operations.

Based on the simple statistical measures and more complex calculations developed by [6] and [4] the BCFI analysis allows for the identification of critical attributes which, in turn, supports managers in the decision- making process.

The research presented in this paper utilized two types of questionnaires in order to gain a more complex understanding of company's operations. The first Balanced Scorecard Questionnaire (BSC) refers to the attributes such as:

- External structure;
- Internal processes;
- Learning and growth;
- Trust;
- Business performance.

The second type of questionnaire- Operational Performance (OP) refers to the operational attributes such as:

- Knowledge and technology management;
- Processes and work flows;
- Organizational systems;
- Information systems.

Respondents were asked to evaluate the present situation within their organizations as well as to refer to their future expectations regarding the same attributes. Respondents were also asked to evaluate the same set of attributes in comparison with competitors. The scale for evaluation stretches from 1 (worst) to 10 (best) and respondents were given certain freedom in interpreting the meaning of values they were assigning to the attributes. Questionnaires also refer to the classification of the attributes in terms of their importance for the development of a company. A division into three groups was implemented and the respondents were asked to divide 100 per cent into the following:

- Basic;
- Core;
- Spearhead.

Attributes classified as spearheads are those that determine the future development of an organization while basic and core capabilities are those typically well-developed that drive the current operations.

The final value of BCFI analysis was calculated by based on the Eq. (1) developed by [6].

$$\frac{\text{SD expc I} * \text{SD expr I} * \text{PI}}{\text{II} * \text{GI} * \text{DDI}}, \qquad (1)$$

where SD expc I – standard deviation expectation index, SD expr I – standard deviation experience index, PI – performance index, II – importance index, GI – gap index, DDI – direction of development index.

The development of the BCFI model has its roots in the need for addressing the complexity of decision making process as well as the multi-dimensional nature of strategies. Moreover, the Balanced Scorecard has been identified as one the most inspiring concepts in the process of BCFI development.

Balanced Scorecard

According to [7] the Balanced Scorecard framework was created based on a need for a multidimensional performance measurement system. The framework provides a holistic perspective on performance measurement that encompasses the following four perspectives:

- Customer;
- Financial;
- Internal business process;
- Learning and growth.

The perspectives are viewed as a set of interlinked relations and the company's strategy should underline the overall concept of the scorecard. According to [7] the significant benefit of the method is the possibility to simultaneously control key performance areas with the help of the key performance indicators characterized by cause and effect relationships. The author emphasizes that the Balanced Scorecard contributed to the way companies are being managed by promoting a holistic approach and simultaneous consideration of dissimilar perspectives. Furthermore, the author claims that the method facilitates the process of reaching consensus in terms of outlining the strategic objectives as well as communication of the chosen strategy. Wu et al. [7] also mention the concept of strategy maps which provide graphical presentation of the results achieved while implementing the Balanced Scorecard. Strategy map represents the process of value creation by connecting the different strategic objectives and assigning them into the aforementioned BSC perspectives. Moreover, strategy maps aim at presenting a macro view of an organization's strategy.

According to [7] the main strengths of the BSC tools comprise of the following:

- Simplicity;
- Interdisciplinary;
- Potential to enhance understanding of the business as well as the cause-effect relationships;
- Aligning intangible assets with company's strategy;
- Supporting corporate restructuring, goal setting, compensation, resource allocation and performance improvement.

According to [7] the major drawbacks of the method are as follows:

The major drawbacks of the BSC framework as mentioned by [7] refer to the weaknesses in design and the implementation failures. Other identified drawbacks concern the insufficient explanation of causality as well as unclear relationships between measures. The framework is also being criticized for its failure to address system dynamics and inability to refer to the time lapse between cause and effect. Another important limitation refers to the small number of indicators. The aim of maintaining the simplicity of the framework should not be compromised however, the key to success is the focus on measuring the "right things".

Despite aforementioned drawbacks the BSC framework can still be described as a beneficial method based on correct and rational assumptions.

The development of the BCFI method aims at adopting the similar logic and creating a tool that would provide an all-encompassing view of organization's situation as well as direct the future development.

The case company

The company chosen for this study develops, manufactures, markets and services low voltage AC drives in the power range of 0.2–5,000 kW, from the simplest to the most demanding applications. The case company's headquarters is located in Vaasa, Finland and it has sales offices and R&D departments in 27 countries in three different continents. The organization aims at building its competitive advantage upon global presence, multiple sales channels, exceptional know-how and innovativeness. Since winning the leadership within the AC drives business requires providing customers with innovative solutions, the company focuses in particular on the research and development as well as shortening the distance to the customer by locating its units worldwide.

The company aims to be a leader supplier of AC (alternating current) drives therefore the strategic choices comprise of product leadership, total focus on AC drives, multi-channel sales network and global presence. The overall ambitious goal of being a leading AC drives imposes investments in research and development as well as maintaining a well-developed customer interface.

The company is constantly facing the challenges that stem from operating in a turbulent environment as well as the growing competition. Moreover, maintaining and coordinating operations worldwide imposes additional challenges in company's operations. Therefore, the process of strategy redevelopment was initiated.

The respondents chosen for the study represent the top management level. For the convenience of analysis they were divided into two groups out of which one represented of "strategy developers" (executive officers, vice presidents) and the "strategy implementers" (directors responsible for the main operations- logistics, global sourcing, business controlling, production testing). The main reason for such division was to examine whether the outlined groups differ in their perception of current situation as well as the expectations regarding the future.

Methodology and research background

Case study approach was implemented in order to address the aforementioned research aims. Single case approach was chosen in order to address the depth rather than the breadth. Nithisathian et al. [8] suggest that single cases are generally recommended for gaining an in-depth and detailed understanding. The study presented in this paper comprises of data collection through a detailed survey. The emphasis was put on gathering quantitative evidence as well as providing description both of the situation in a given point of time and the expected development in the future.

The research presented in this report was based on the survey conducted in the company. The representants of different management levels were selected for the research and all together 14 responses were gathered. The responses were divided into two following groups:

- group 1 (employees responsible for strategy crafting; 5 answers in total),
- group 2 (employees responsible for strategy execution; 6 answers in total).

Weak market test

The weak market test was conducted in order to validate the results of the empirical research as well as to determine whether the model would require any corrections. The results of the weak market test revealed certain discrepancies between the suggested directions of development and the perception of the company's president. Therefore, the method should be given additional attention especially in terms of calculating the formulas and the meaning of statistical measures.

The weak market test was conducted with the president of the company. The interviewee was asked to comment on the proposed directions of development. As it can be observed from the tabular summaries there is a significant resistance towards the proposed increase of attributes. Such results suggest that there might be some weaknesses in the method in terms of the construct of questionnaire or the formulas.

Presentation and interpretation of the results

The empirical data gathering was accomplished through a survey distributed among employees of the case company. The respondents were asked to express their opinions on the aforementioned attributes in terms of both present and their future development. To facilitate the process of data analysis the respondents were asked to express their opinions by assigning values from 1 (lowest, the worst) to 10 (highest,

the best) to their opinions.

The aim of the presented research was, apart from providing guidelines for the case company, testing the method for its potential flaws and weaknesses. In particular, the weak market test was expected to provide a valuable insight into rethinking the method.

Figures 1 and 2 presents the resuls of BCFI (OP and BSC questionnaires) calculations for group 1. Figures 3 and 4 present the same calculations for group 2. Graphs present the tendencies for the past and the future (experiences and expectations).
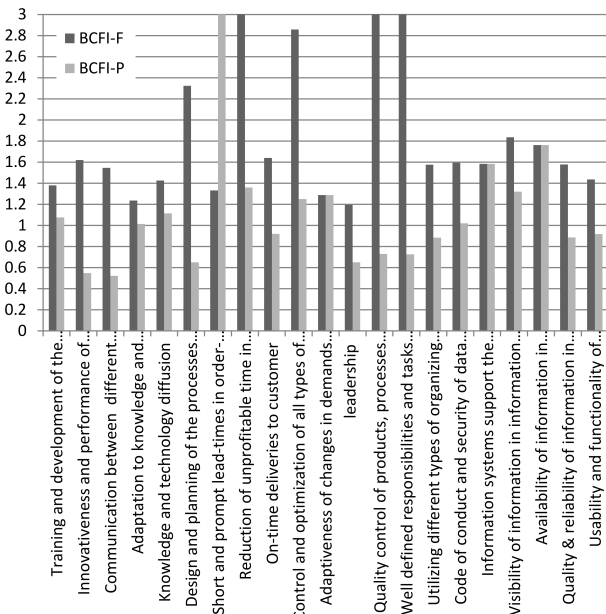
Fig. 1. BCFI calculations for group 1
(OP questionnaire).
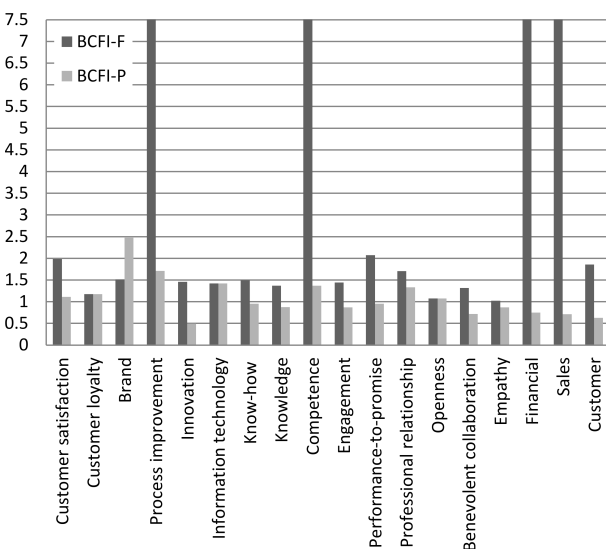
Fig. 2. BCFI calculations for group 1
(BSC questionnaire).
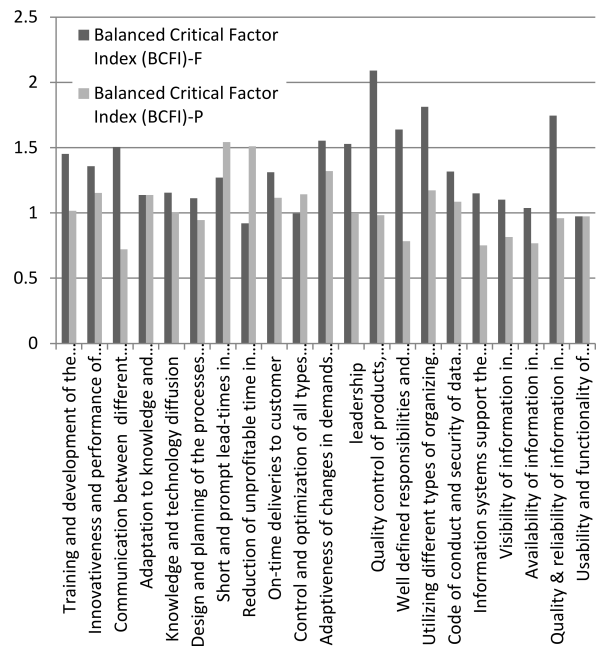
Fig. 3. BCFI calculations for group 2
(OP questionnaire).
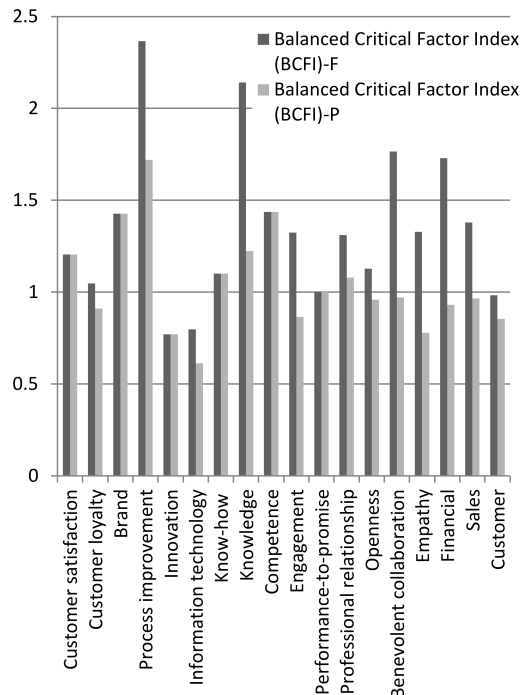
Fig. 4. BCFI calculations for group 2
(BSC questionnaire).

Based on the values of the calculated BCFIs the attributes were divided into critical (requiring immediate action), green ones (not requiring immediate action however, should be monitored), and yellow ones (unclear in their meaning). Based on the numerical values calculated for every attribute the division was made and suggestions for the future de-

velopment were outlined. Tables 1 and 2 present the suggestions contrasted with the results of the weak market test during which the company's president commented on the proposed improvements (agree or disagree).

Table 1
Directions of development and the results of the weak market test (group 1)

attribute	suggestion	comments
Adaptation to knowledge and technology	increase	agree
Adaptivennes of changes in demands and order backlog	increase	agree
Empathy	increase	agree
Openness	increase	agree
Customer loyalty	increase	agree

Table 2
Directions of development and the results of the weak market test (group 2)

attribute	suggestion	comments
Control and optimization of all types of inventories	increase	agree
Usability and functionality of information systems	increase	agree
Innovation	increase	agree
Information technology	increase	agree
Communication between different departments and hierarchy levels	increase	disagree

Improvement suggestions were presented in terms of the attributes that require attention or, in other words, need to be increased. It is assumed that available resources are limited and therefore, more resources allocated into certain areas might imply that the development of other potentially important areas would have to be at least temporarily abandoned. Since such a tradeoff is challenging to address, this paper does not provide clear suggestions regarding the decrease of certain attributes. The further development of the model will be focused on sharpening the suggestions regarding the decrease. Currently, the results provided by the model are not reliable enough to serve as basis for outlining the managerial implications.

Conclusions

The empirical study was intended to examine a set of attributes divided into two separate question-

naires. Based on simple statistics and more complicated calculations the attributes were examined in terms of their criticality. According to [4] the final value of the Balanced Critical Factor Index (BCFI) can serve as a basis for division into critical, not critical or unknown. The factors influencing the final value of BCFI are: standard deviation index (relating to past and future), performance index, importance index, gap index, and direction of development index. The indexes rely on the values of standard deviation and therefore the number of respondents is critical and should preferably be at least five. The number of respondents for this empirical research was 11 which support the validity of results. The process of coding the responses did not reveal any serious mistakes or misunderstanding therefore all the responses were considered usable.

The weak market test was conducted in order to validate the results of the analysis and its results revealed several challenges regarding the interpretation of the suggested directions of development. Therefore, the question of the reliability of the final formula appeared. One of the opportunities for the future research is redesigning the final BCFI equation or its components in order to avoid extremely high values caused by the variance in responses.

The final values of BCFI served as a reference for determining whether a given attribute is critical or not. Determining the criticality of attributes was followed by the suggestions regarding the resource allocation (assign more resources, assign less resources or restrain from any actions). Therefore, the method not only beneficial for the critical evaluation of company's current situation by also of is directly useful in the decision-making process and supports the understanding the organization's situation in terms critical attributes.

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SMEs' PERFORMANCE EVALUATION
AND OPTIMIZATION BASED ON DEA AND CFI

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ABSTRACT

It is a core content of enterprise performance research evaluating and comparing enterprise performance in dynamic environment. In allusion to this problem, a variety of enterprise performance assessment methods and indexes systems are proposed. Data envelopment analysis (DEA) is a kind of effective mathematical model which is used for comparing the performance among enterprises or different units inside an enterprise, based on the real-world data. Through comparing the performance, DEA can evaluate the enterprise performance from scale effectiveness and technological effectiveness, and then get the performance optimization goals. Critical Factor Index (CFI) is a new enterprise performance assessment method proposed in recent years. This method, based on the performance perception of business leaders or staffs, evaluates the enterprise performance in different dimensions, and then gets the optimization strategy of enterprise resource allocation to improve integrated enterprise performance. This paper has structured a new evaluation and optimization system for performance of small and medium-sized enterprises (SMEs), which combine properly the DEA and CFI method to evaluate and optimize the SMEs' performance comprehensively, and has confirm this system with data of 5 Finnish SMEs.

KEYWORDS

data envelopment analysis (DEA), critical Factor Index (CFI), small and medium-sized enterprises (SMEs), performance evaluation, optimization.

Introduction

The unit of analysis in this study is a manufacturing focused Small and Medium-sized Enterprise (SME). The definition of SME is different in different contexts. The US context offers multiple definitions of SME depending on the industry. For example, in some industries, SME is a company having less than 500 employees. In the European context, the SME is a company having less than 250 employees. This difference on definitions needs to be taken into account. Ayyagari et al. [1] covers this topic in his globally focused, statistical study on SMEs (p. 416): The term SME covers a wide range of definitions and measures, varying from country to country and vary-

ing between sources reporting SME statistics. Some of the commonly used criteria are the number of employees, total net assets, sales, and investment level. However, the most common basis for definition is employment, and here again, there is variation in defining the upper and lower size limit of an SME. Despite this variance a large number of sources define an SME to have a cut-off of 250 employees [1]. Because of the case context, the European definition is utilised. Within the SME category, the European Union defines medium sized firms as having 50-249 employees, small firms as having 10-49 employees, and micro firms as having 0-9 employees [2].

In the recent literature, Small- and medium sized companies (SME's) are considered to be an impor-

tant and integral part of every country's economy; the fastest growing sector of many economies, more flexible and adaptable in terms of structure and having a faster speed of response than larger organizations [3]. SMEs are often associated with a higher economic growth of nations [4]. The impact of SMEs on employment is significant [5]. On the other hand, compared to large enterprises, SMEs typically have fewer financial resources, lower technical expertise, and more limited management skills [6]. A large SME sector as such does not directly cause economic growth, but is indeed a key characteristic of successful economies. A successful SME sector can be considered a vital part of the growth and development in sparsely populated regions [7]. The 'early stages' of firms is a critical period for their survival and success as well as significant portion of firms fail during their early years of existence. Serving this group of companies well is an important challenge for public business services.

The companies analysed in this study are located in the Oulu South region. The region is located in Finland in the southern part of Northern Ostrobothnia. Oulu South is not a governmental unit or area–It was formed to increase inter-municipal co-operation and to gain the critical mass for national and international competitiveness. The region consists of three sub regions and 14 municipalities with about 90 000 inhabitants. Oulu South is one of the main rural areas in Finland. Oulu South is characterized as an entrepreneurial and industrialized countryside, which offers one of the lowest employment rates in northern Finland. The demographic challenge is emigration from the area. On the other hand, the proportion of young people seems to remain high because of high birth rate. There are about 4600 active companies in Oulu South; the majority of them (95%) are micro-sized companies.

Research Methodologies

Analytical model: System of SMEs' Performance Evaluation and Optimization

As a kind of Sense & Respond model, Critical Factor Index (CFI) model can evaluate and balance the internal resources of enterprise in every aspect to improve the utilization efficiency of resource [8]. But CFI model still have three problems in SMEs' performance evaluation and optimization. First, CFI model mainly evaluates the resource allocation performance inside the enterprise based on the comparison among the indexes within enterprise. But it cannot evaluate resource performance in the whole or dimension level, especially can't compare the performance among

enterprises. Second, CFI model can determine the critical indexes very well, but cannot confirm the excess input indexes. Third, CFI model mainly evaluates indexes from the view of resource input, but not from the view of efficiency of resource utilization. As a kind of performance evaluation model based on accurate data, DEA can evaluate the efficiency of resource utilization and the trend of resource input changes affecting performance on the base of performance comparison among dimensions. Therefore, the joint usage of DEA and CFI method can structure a complete system which can simultaneously evaluate and optimize SMEs' performance from the view of resource input and efficiency of resource utilization.

(1) Index System of SMEs' Performance Evaluation and Optimization

The SMEs' performance can be evaluated from three dimensions: dynamic capability, technological innovation capability and enterprise competitiveness.

Dynamic capability is mainly set for enterprise flexibility evaluation in resource and decision. It is mainly measured by the performance of adaptive process of enterprise in environmental changes. Dynamic capability is an important aspect of comprehensive performance of enterprises. At present, rapidly changing global business environment has set higher requirements in environment adaptability, rapid response capability and risk decision-making capacity to enterprises, especially to SMEs [9]. Compared with large enterprises, SMEs have the characteristics of smaller size, simple organization structure, fewer available resources and so on. These characteristics has caused that their risk resistance capacity is weaker and organization flexibility is stronger. Therefore, in face of the environmental changes, avoiding risk and adapting to the environment through rapid strategic realignment is the optimal choice of SMEs. And dynamic capability has become a decisive factor for survival and development of SMEs.

Technological innovation capability (ETIC) is mainly set for enterprise performance evaluation in technological innovation and keeping technological competitiveness. It is mainly measured by the performance of input-output efficiency in technological innovation and technological innovation system. For modern enterprises, the technological innovation is undoubtedly a very important capability. The advanced technology is the source of profit and competitiveness to enterprises, and at the same time, it is also an important support which helps enterprises adapt market changes. Along with the unceasing renovation of technology of industry, enterprises must

continually adapt to the technical requirements of market. For SMEs, the technological innovation is all the more a decisive factor for survival and development. In the state of that the economies of scale cannot be achieved, the high technical added value and advanced production process are the keys of that SMEs preserve profit and reduce costs.

Enterprise competitiveness is mainly set for the whole competitiveness of enterprises. It is mainly measured by the performance of production and capital utilization. Enterprise competitiveness is the ultimate expression of comprehensive performance of enterprises, and also a basic dimension of performance evaluation. Through enterprise competitiveness evaluation, the comprehensive performance of enterprises in organization, operation and production can be embody, so enterprise competitiveness evaluation is an essential part of SMEs' performance evaluation.

According to the three dimensions of SMEs' performance evaluation and optimization and the essential requirements of DEA model and CFI model, the index system of SMEs' performance evaluation and optimization is designed as Table 1.

Table 1
Index system of SMEs' performance evaluation and optimization

Dimensions	Index types	DEA Index System	CFI Index System
		DEA Indexes	CFI Indexes
Dynamic capability	Input	The cost of adapting to the change of market	Information systems support the business processes
		Response time of the change of market	Visibility of information in information systems
		The time of market change perception	Availability of information in information systems
		The value of resources invested before the change of market	Quality & reliability of information in information systems
	Output	The rate of sales change of product caused by the change of market	Usability and functionality of information systems
		The rate of qualified rate changes of product caused by the change of market	Short and prompt lead-times in order-fulfillment process
		The value of resources successfully transformed after the change of market	Adaptiveness of changes in demands and in order backlog
		The value of newly added resources after the change of market	
Technological innovation capability (ETIC)	Input	R&Dfunds inputs	Training and development of the company's personnel
		Proportion of R&D staffs	Innovativeness and performance of research and development
		Marketing expenditure of new product (per annum)	Communication between different departments and hierarchy levels
		The investment for Technology resources absorption(per annum)	Adaptation to knowledge and technology
	Output	The rate of return of new product	Knowledge and technology diffusion
		The sales revenue of new product	Design and planning of the processes and products
Enterprise competitiveness	Input	Total cost of production (per annum)	Reduction of unprofitable time in processes
		Staff quantity	On-time deliveries to customer
		Marketing expenditure (per annum)	Control and optimization of all types of inventories
		The investment of business cooperation	Leadership and management systems of the company
		The Total Assets of enterprise	Quality control of products, processes and operations
	Output	The product sales revenue (per annum)	Well defined responsibilities and tasks for each operation
		Market Share	Utilizing different types of organizing systems (projects, teams, processes...)
		The profit of business cooperation	Code of conduct and security of data and information

(2) Construction of the DEA model

According to index system of SMEs' performance evaluation and optimization, the three dimensions need to be evaluated separately by DEA as independent decision points. The resource input and ultimate performance of every decision points can be regarded as the activity that a decision making unit (DMU) output a number of 'products' through input a number of factors of production. There are some differences in details, but their objectives are all for gaining the maximum economic benefits in the activity. Therefore, the evaluating enterprise and each similar competitive enterprise can be regarded as a DMU, and the technical efficiency of evaluating enterprise can be evaluated with the C^2R model, and the pure technical efficiency of evaluating enterprise can be evaluated with BC^2 model, and the scale efficiency of evaluating enterprise can be evaluated with the ratio of technical efficiency to pure technical efficiency. Due to evaluation of each dimension consist of multiple input indexes and multiple output indexes, the subscripts i is used for representing the i-th input, and the subscripts u is used for representing the u-th output. The number of input indexes and output are supposed separately to be p and q.

First, the technical efficiency of enterprises is analyzed with DEA model $(D^\varepsilon_{C^2R})$ which has Non-Archimedean infinitesimal presented by Charnes and Cooper.

$$D^\varepsilon_{C^2R} \begin{cases} \min\left[\theta - \varepsilon\left(\sum\limits_{i=1}^{p} s_i^- + \sum\limits_{u=1}^{q} s_u^+\right)\right] \\ \sum\limits_{j=k}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{io} \\ \sum\limits_{j=1}^{n} x_{uj}\lambda_j - s_u^+ = y_o \\ \lambda_j, \ s_i^-, \ s_u^+ \geq 0, \ j = 1, 2, ..., n, \\ \quad i = 1, 2, ...p, \ u = 1, 2, ...q \end{cases} \quad (1)$$

where θ is the technical efficiency value of the evaluating enterprise in one dimension, x_{ij} and y_{uj} are the i-th input and the u-th output of the j-th DMU, λ_j is the linear combination of n DMUs, s_i^- is the excess input amount of i-th input index, s_u^+ is the insufficient output amount of u-th output index.

- Technical efficiency evaluation. If the optimal solution of linear programming model $D^\varepsilon_{C^2R}$ is θ^0, λ_j^0, s_i^{-0}, s_u^{+0}, then the results as follow can be got according to DEA theory.

  a) If $\theta^0 = 1$, $s_i^{-0} = 0$, $s_u^{+0} = 0$, then the DMU$_{j0}$ is DEA efficiency, and the DMU$_{j0}$ is scale optimum and technical optimum simultaneously in this dimension.

  b) If only $\theta^0 = 1$, then DMU$_{j0}$ is weak DEA efficiency, and the DMU$_{j0}$ can't get scale opti-

mum and technical optimum simultaneously in this dimension.

  c) If $\theta^0 < 1$, then DMU$_{j0}$ is DEA inefficiency, and the DMU$_{j0}$ is not scale optimum and technical optimum in this dimension.

- Scale efficiency evaluation. If there exists a value λ_j^0 under the condition of which $\sum \lambda_j^0 = 1$, then DMU$_{j0}$ is constant returns to scale. If there don't exists a value λ_j^0 under the condition of which $\sum \lambda_j^0 = 1$, and $\sum \lambda_j^0 < 1$, then DMU$_{j0}$ is increasing returns to scale. If there don't exists a value λ_j^0 under the condition of which $\sum \lambda_j^0 = 1$, and $\sum \lambda_j^0 > 1$, then DMU$_{j0}$ is diminishing returns to scale.

- Improvement target. If the evaluate result is weak DEA efficiency or DEA inefficiency, this DMU will need to be improve. If $s_i^{-0} > 0$ and s_u^{+0}, it means this DMU's input is excess or output is insufficient. The improvementobjectiveis.

$$\begin{cases} \widehat{x}_{ij0} = \theta^0 x_{ij0} - s_i^{-0}, \\ \widehat{y}_{ij0} = y_{uj0} + s_u^{+0}. \end{cases} \quad (2)$$

Second, the pure technical efficiency of enterprises in one dimension is analyzed with DEA model (BC^2) presented by Banker.

$$D_{EC^2} \begin{cases} \min\left[\sigma - \varepsilon\left(\sum\limits_{i=1}^{p} s_i^- + \sum\limits_{u=1}^{q} s_u^+\right)\right] \\ \sum\limits_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \sigma x_{io} \\ \sum\limits_{j=1}^{n} y_{uj}\lambda_j - s_u^+ = y_o \\ \sum\limits_{j=1}^{n} \lambda_j = 1 \\ \lambda_j, \ s_i^-, \ s_u^+ \geq 0, \ j = 1, 2, ..., n, \\ \quad i = 1, 2, ...p, \ u = 1, 2, ...q. \end{cases} \quad (3)$$

This model fixes the scale efficiency, thus the pure technical efficiency can be evaluated with this model. The optimal solution of the DEA model (BC^2) is assumed to be σ^0, λ_j^0, s_i^{-0}, s_u^{+0}, then the results can be got according to DEA theory. If $\sigma^0 = 1$, $s_i^{-0} = 0$, $s_u^{+0} = 0$, then DMU$_{j0}$ is DEA efficiency, and the pure technical efficiency is optimum. Otherwise, DMU$_{j0}$ is DEA inefficiency the pure technical efficiency is not optimum.

If the DEA evaluation result of evaluating enterprise in one dimension is DEA efficiency, it proves the operational efficiency of evaluating enterprise is good. The evaluating enterprise only need to increase appropriately the resource input in the critical index determined by CFI model to impel the critical index to get back into the normal state, but not adjust greatly the existing input-output framework.

If the DEA evaluation result of evaluating enterprise in one dimension is that the pure technical efficiency of evaluating enterprise is optimum, the resource input in this dimension need to be adjusted. According to the different results of scale efficiency evaluation, there are two cases as follow.

a) Increasing returns to scale. In this cases, the evaluating enterprise need to input lots of resources in the critical index determined by CFI model, and try to input more resources in normal index with lower score to enlarge the overall scale in the dimension, and then to increase efficiency in the dimension.

b) Diminishing returns to scale. In this cases, the evaluating enterprise only need to input appropriately some resources in the critical index determined by CFI model, and give priority to the normal index of this dimension in selecting objects of decrease resources.

If the DEA evaluation result of evaluating enterprise in one dimension is that the scale efficiency of evaluating enterprise is optimum, it proves there are some problems in resources input structure of this dimension. Therefore, the evaluating enterprise can consider adjusting resource structure within the dimension based on the results of CFI evaluation.

If the DEA evaluation result of evaluating enterprise in one dimension is DEA inefficiency, the evaluating enterprise can consider balancing resource within the dimension, and adjusting resource input structure while increasing or reducing the resource input based on the results of scale efficiency evaluation. Then the evaluating enterprise needs to readjust operation structure and organization structure, and carry forward the organizational restructuring and strategic remanufacturing.

(3) Construction of the CFI model

The Critical Factor Index (CFI) method is a measurement tool to indicate which attribute of a business process is critical and which is not, based on the experience and expectations of the company's employees, customers or business partners [10]. In the current business environment strategic decision marking and fast adaption requires a reliable and efficient method to sense and respond customer satisfaction for management purpose [11]. By the detection and abstraction of the most critical attributes which are affecting the business performance of a company both on a current moment and future perspective (5–10 years), the CFI method is able to conduct and interpret tacit knowledge which existing inside or outside of company to take deliberate strategic steps in a short period of time [12]. The key factors can be given as blew:

Gap Index – helps to understand the gap between the expectation and experience of a particular attribute, therefore to clarify if the company's expectations are correct and corresponding to the reality.

$$\text{Gap index} = |(\text{avg of experience} - \text{average of expectation})/10 - 1|. \quad (4)$$

Direction of Development Index – demonstrates the actual positive or negative change of an attribute's performance. The index provides us with the information about the actual direction of the company's development.

$$\text{Direction of development} = |(\text{Better \%} - \text{Worse\%})/100 - 1|. \quad (5)$$

Importance Index – demonstrates the level of importance of an attribute among the others. The index reflects the actual expectations of the company regarding an attribute. Anyhow, the expectation may not correspond to the experience.

$$\text{Important index} = \text{avg. of expectation}/10. \quad (6)$$

Performance Index – reflects the value of an attribute's performance based on the actual experience of the respondents. In the result we can see either an attribute has performed well or not and make the conclusion about the attribute importance.

$$\text{Performance index} = \text{avg. of experience}/10. \quad (7)$$

Standard Deviation Expectation Index – reflects the fact if the respondents have similar or controversial meaning regarding all the attributes' expectations.

$$\text{SD expectation index} = \left(\frac{\text{SD of expectation}}{10}\right) + 1. \quad (8)$$

Standard Deviation Experience Index – reflects the fact if the respondents have similar or controversial meaning regarding all the attributes' experiences.

$$\text{SD experience index} = \left(\frac{\text{SD of experience}}{10}\right) + 1. \quad (9)$$

Operational competitiveness analysis of case study

The main role of the case study is to present the results of the DEA and CFI evaluations as well as to show method validation such as how it was organized. In other words, Results section reflects empirical data and the practical experience gained during the research. The case companies took part in the research demonstrates the evaluation and performance

of research models. The basic information about the participants, their field of activity and number of respondents is necessary for the research creditability and forms a deeper understanding of the research area. The company information represented in research is confidential; therefore the official names of the case companies will not be appeared in this case study.

(1) CFI analysis

By analyzing data from case company and combining CFI method with index system of SMEs' performance evaluation, all critical factors have been grouped and evaluated into three dimensions: Dynamic capability, Technological innovation capability and Enterprise competitiveness; the data is presented in the Fig. 1.

In the dimension of dynamic capability, the factor of "Short and prompt lead-times in order fulfillment process" reflects huge uncertainty for its trend, it does not show creditability of the model research, this factor should be paid more attention for its uncertainties. In this dimension group, most of critical factors reflect better performance in future except the factor "Availability of information and information system", this factor should be taken more

awareness and importance by managers for its future perspective.

In the dimension of technological innovation capability, most critical factors keep their level and general performance is slightly better in future, however the factor "Adaptation to knowledge and technology" reflects deteriorated performance in future perspective, so this factor should be taken into consideration in order to keep its level and ensure its better performance in the future.

The general performance in dimension of enterprise competitiveness deteriorates in the future regarding to most of critical factors. Typically, two critical factors "On-time deliveries to customers" and "well defined responsibilities and tasks for each operation" have worst performance and these two critical factors have to be awaked and improved by decision makers for their future perspective and importance.

(2) DEA analysis

For further validating the effectiveness of the new SMEs' performance evaluation and optimization system, this paper has surveyed 5 SMEs, among which the enterprise A is as the research sample of this paper. The DEA result which is calculated by DEAP software is showed in Table 2 as follow.
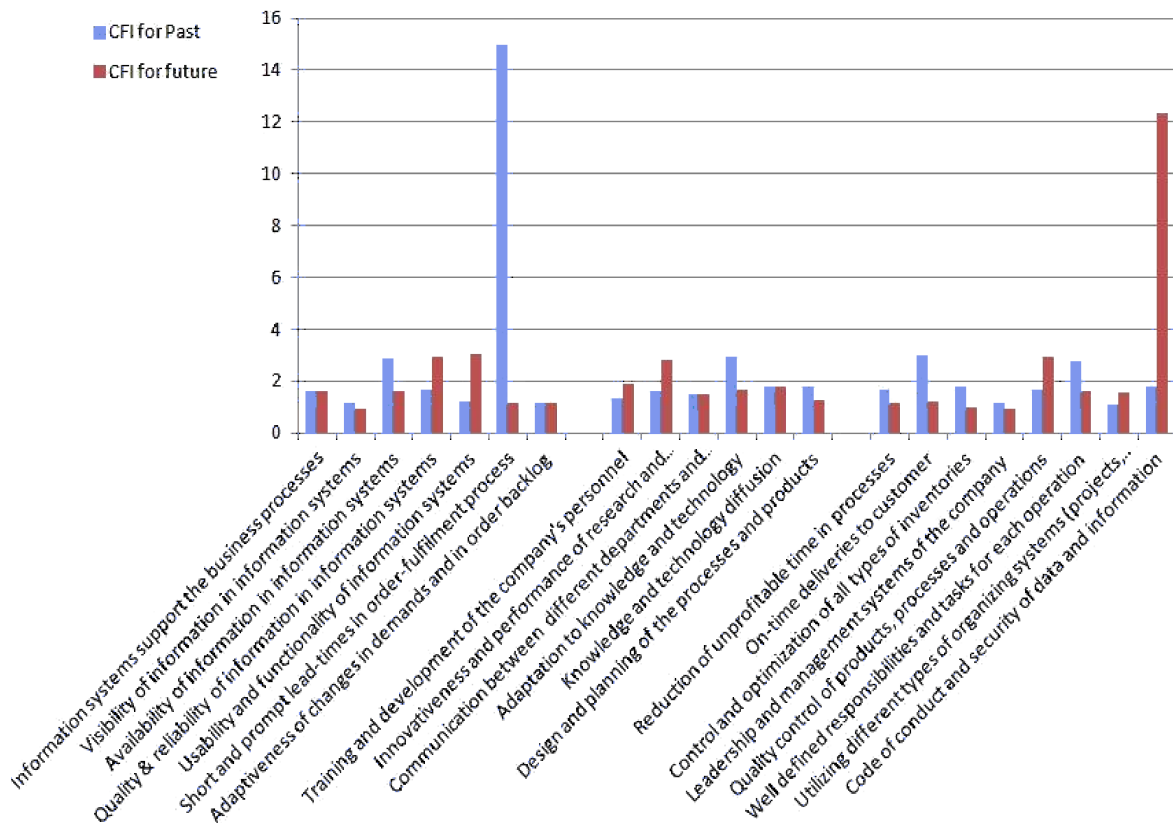
Fig. 1. The data result of CFI analysis [12].

Table 2
The DEA analysis of enterprise A.

Dimensions	DMU	θ^0	σ^0	s^0	s_1^{0-}	s_2^{0-}	s_1^{0+}	s_2^{0+}	s_3^{0+}	scale efficiency
Dynamic capability	A	0.343	1.000	0.343	0.071	–	0.000	6.000	–	increase
	B	1.000	1.000	1.000	0.000	–	0.000	0.000	–	–
	C	0.229	1.000	0.229	0.213	–	0.000	6.000	–	increase
	D	0.160	1.000	0.160	0.300	–	0.000	4.000	–	increase
	E	0.800	1.000	0.800	0.000	–	0.000	0.000	–	increase
Technological innovation capability (ETIC)	A	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	-
	B	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	–
	C	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	–
	D	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	increase
	E	0.270	0.270	1.000	0.000	0.000	0.052	0.000	0.000	–
Enterprise competitiveness	A	0.543	0.657	0.827	0.000	0.000	0.053	0.000	0.008	increase
	B	0.669	0.669	0.999	0.000	0.000	23.934	0.000	0.976	increase
	C	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	–
	D	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	–
	E	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	–

According to the DEA results, the enterprise A is DEA efficiency in ETIC dimension, but in dynamic capability dimension, enterprise A is pure technical efficiency, and in enterprise competitiveness dimension, enterprise A is DEA inefficiency. Therefore, the conclusioncan be got as follow.

- In dynamic capability dimension, the pure technical efficiencyof enterprise A is optimum, and the result of scale efficiency evaluation is increasing returns to scale. The enterprise A need to input lots of resources in the critical index determined by CFI model, and try to input more resources in normal index with lower score to enlarge the overall scale in the dimension, and then to increase efficiency in the dimension.
- In enterprise competitiveness dimension, the enterprise A is DEA inefficiency, and the result of scale efficiency evaluation is increasing returns to scale. The enterprise A need to input lots of resources in the critical index determined by CFI model, and adjusting resource input structure while increasing the resource input. Then the enterprise A needs to readjust operation structure and organization structure, and carry forward the organizational restructuring and strategic remanufacturing.

Discussion

SMEs are the hard core of the equipment manufacturing industry of developed countries, and it is also the crucial driving power of economic development in Europe and America. Therefore, the method of SMEs' performance evaluation and optimization

is the focal point of performance evaluation research field. At present, there are various performance evaluation methods in performance evaluation research field, among which the more common methods are Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP), and so on. These methods are with different characteristics and different disadvantages. In comparison, DEA is more objective, but this method is always restricted by the authenticity and statistic standard of data due to the high requirements of data quality. In addition DEA can only analyze the efficiency of production or operation, but can't combine with corporate strategy and leadership. CFI method is a kind of evaluation method based on AHP. Similar to AHP, CFI method is very easy to obtain data and combine with corporate strategy and leader thought, but this method is always affected by the validity of data and the personal subjective factors of survey respondents. The applications scope of CFI is limited, and it is incomparable. The new SMEs' performance evaluation and optimization system which combine the DEA and CFI presented by this paper has combined the advantages of the two evaluation methods. This system uses DEA in dimension level to evaluate the performance of dimensions and support the following resources allocation optimization based on the comparison of the target enterprise and its major competitors. And then the system uses CFI in Index level to evaluate and optimize the resource allocation of dimensions. It is very clear that the new SMEs' performance evaluation and optimization system presented by this paper can compare the current situation of indexes with major competitors and enterprise strategic objectives simultaneously, and it

can evaluate and optimize the SMEs' performance in the whole process.

Practice is an important way to test the validity of a new method. The DEA and CFI method has been tested by a lot of case study, and accepted by academia. For further validating the effectiveness of the new SMEs' performance evaluation and optimization system, this paper has surveyed 5 SMEs. These 5 SMEs all belong to industrial manufacturing enterprises, and have a certain degree of similarity in scale, organization structure and business model. Therefore, these 5 SMEs fit to the requirements of DEA and CFI. The comparison between the analysis results and the feedback result of 5 SMEs shows that the new system has validity in the performance evaluation and optimization practice, and it can provide enterprises with efficient proposals of resource optimization. This research will further large-scale use the method in future research to further test and verify it.

Conclusion

In this paper, a new SMEs' performance evaluation and optimization system has been built by the research of combining effectiveness of DEA performance evaluation model and resource-utilization of CFI performance evaluation model. The key focus is to combine and leverage two models together with comparing difference of effectiveness in enterprise and its main competitors within each dimension in order to perceive inefficiency in the enterprise and support CFI optimization strategy. By applying CFI and DEA evaluation methods, the resource allocation and utilization within the enterprise can be balanced and optimized. Therefore, the system in theory provides valuable evaluation and optimization capabilities for enterprises' resource allocation and utilization. To access creditability of the system, one mid-sized case company has been investigated with in-depth research of 5 SMEs, the case results show that the new system has high degree of validity in reality, which provides efficient supports for performance evaluation and decision optimization in enterprises.

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SENSITIVITY ANALYSIS OF KEY CUSTOMERS AND REVENUE-ORIENTED ADMISSION CONTROL AND SCHEDULING ALGORITHM

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ABSTRACT
The paper deals with the problem of Quality of Web Service (QoWS) in e-commerce Web servers, i.e. in retail Web stores. It concerns the admission control and scheduling algorithm for a Web server system, which aims at preventing the system from overload to provide high QoWS level and ultimately, to increase Web site's conversion rate, i.e. to turn more visitors into customers. The sensitivity of the algorithm to changes in its basic parameter values was analyzed by using a simulation-based approach. Special attention was paid to evaluation of the parameter impact on conventional and business-related system performance metrics.

KEYWORDS
Quality of Web Service, QoWS, Web server, e-commerce, simulation, conversion rate

Introduction

Due to the still increasing number of Internet users and intensive development of Web-based technologies, contemporary Web servers have to face with highly variable and unpredictable service demand. Server systems are designed to be capable of handling peak loads, usually through overprovision of their resources. However, it is unavoidable that during extremely high traffic bursts server resources are overutilized and the server is overloaded. Consequently, request response times increase excessively and users experience unacceptably high delays.

Such situation is especially undesirable for e-commerce applications, including B2C (*Business-to-Consumer*) applications, i.e. retail Web stores. As a result of poor QoWS (*Quality of Web Service*), online retailers loose potential revenue and let their loyal customers down. Even if a company applies a customer-focused strategy and uses advanced CRM (*Customer Relationship Management*) techniques, the company's effort may be thus thwarted.

One of possible ways of coping with this problem is introducing a method for differentiated request service in the Web server system. A number of such methods have been dedicated to e-commerce servers, e.g. in [1–7]. What distinguishes these approaches from others is the goal of revenue maximization, as well as taking into consideration characteristics of user sessions in a Web store, such as session states corresponding to types of business operations performed in the store, probabilities of transitions between the states, session lengths, and the contents of shopping carts.

This paper refers to KARO (<u>K</u>ey customers <u>A</u>nd <u>R</u>evenue <u>O</u>riented admission and scheduling) method and KARO-Rev (*KARO – <u>Rev</u>enue-oriented*) algorithm, which were presented in [4] in detail. The next section briefly outlines the idea of

the method and presents the algorithm, for which results of simulation experiments will be discussed further.

Key customers and revenue-oriented QoWS mechanism

We consider a B2C Web site which is equipped with a Web server allowing Internet users – potential customers to browse and search for products, add them to the shopping carts, confirm purchase transactions, and so on, like in a traditional, brick-and-mortar store. A single user's visit to the Web site is called a *user session.*

Every time a user opens a new page of the Web site, his or her browser generates a sequence of HTTP requests which are sent to the Web server (the first request in the sequence is for an HTML file and subsequent requests are for objects embedded in the page, such as graphic files). Many users may visit the store at the same time.

HTTP requests come to the Web server and are queued and processed in the system usually according to FIFO (*First In First Out*) policy. Here we assume that the whole system is organized as a multi-tier system, in which requests are processed at three logical layers: Web server, application server and database server. Some requests are processed only by the Web server whereas other have to be additionally processed by the back-end server as dynamic requests (Fig. 1).
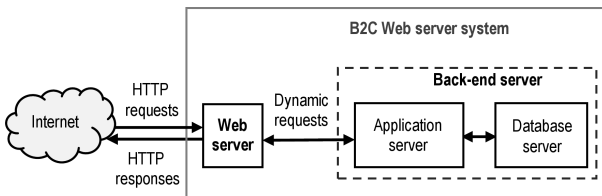
Fig. 1. Multi-layer configuration of a B2C Web site [4].

Idea of KARO method

The basic idea of KARO method is the periodical computation of customer values, storing them in a customer database on the Web server and using them in an automated process of HTTP request service in a Web store [4]. The customer value is determined by using RFM analysis and is calculated according to the following formula:

$$CVS = w_R \times R + w_F \times F + w_M \times M, \quad (1)$$

where R, F, M are codes of behavioral variables for the customer: recency, frequency and the monetary value, respectively, and w_R, w_F, w_M are weights as-

signed to the corresponding behavioral variables according to the business strategy of the company.

KARO method extends the Web server system with the ability to give the precedence of service to requests from users who are likely to confirm a purchase and to requests from users who are the most valuable customers. Requests are handled taking into consideration sessions they belong to. Each i-th HTTP request which belongs to the p-th page in user session s is denoted by x_{ip}^s and a corresponding dynamic request is denoted by y_{jp}^s.

Each active user session at the n-th moment is described with a number of attributes, which together determine the importance of the session from the e-business perspective. The attributes of session s at the n-th moment include:

- the session class, $c^s(n)$, which may mean a key customer (KC) or an ordinary customer (OC);
- the session rank, $RFM^s(n)$, reflecting the customer value, which corresponds to key customer's CVS read from database or is zero for an ordinary customer;
- the session state, $e^s(n)$, corresponding to one of the following business operations: entry to the home page (H), logging on (L), browsing (B), searching for products (S), product details (D), adding a product to the shopping cart (A), registration (R), or purchase confirmation (P);
- the financial value of products in the shopping cart, $v^s(n)$;
- the session length, $l^s(n)$, i.e. the number of pages visited in the session until the n-th moment.

The attributes of session s determine the session priority at the n-th moment:

$$P^s(n) = \begin{cases} 4 \text{ for } (c^s(n) = KC) \vee [(c^s(n) = OC) \\ \quad \wedge (v^s(n) > 0) \wedge (e^s(n) = P)], \\ 3 \text{ for } [(c^s(n) = OC) \wedge (v^s(n) > 0) \\ \quad \wedge (e^s(n) \neq P)] \vee [(c^s(n) = OC) \\ \quad \wedge (v^s(n) = 0) \wedge (l^s(n) < T_{Med})], \\ 2 \text{ for } (c^s(n) = OC) \wedge (v^s(n) = 0) \\ \quad \wedge (T_{Med} \leq l^s(n) < T_{Low}), \\ 1 \text{ for } (c^s(n) = OC) \wedge (v^s(n) = 0) \\ \quad \wedge (l^s(n) \geq T_{Low}), \end{cases} \quad (2)$$

where T_{Med} and T_{Low} ($T_{Med} < T_{Low}$) are predefined thresholds which determine three ranges for the session length. The priority 4 is the highest possible priority value, assigned to most important sessions, and the priority 1 is the lowest possible priority.

To support differentiated QoWS in the system, admission control (AC) under the system overload together with priority-based scheduling in front of the Web server (in queue Q_1) and in front of the

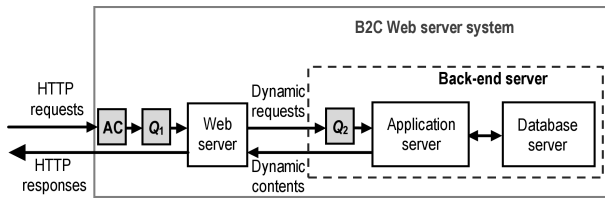back-end server (in queue Q_2) have been proposed (Fig. 2).

Fig. 2. Multi-layer configuration of a B2C Web site according to KARO method.

The indicator of system load intensity is the length of queue Q_2 at the n-th moment, $L(n)$. Admission control is based on two thresholds for system load intensity, I_1 and I_2 ($I_1 < I_2$). Depending on the current system load and the session priority, some requests may be rejected under overload at the Web server input. On the other hand, priority scheduling in queues Q_1 and Q_2 makes it possible to change the order of request execution at the Web server and the back-end server, respectively. For each queue a strict priority scheduling is applied between four priorities, i.e. all higher-priority requests are queued before the lower-priority ones.

KARO-Rev algorithm

The session priorities and attributes are used in the request admission control and scheduling algorithm KARO-Rev [4].

For each new admitted HTTP request and each new dynamic request, the request position in the corresponding queue (Q_1 for an HTTP request and Q_2 for a dynamic request) is determined. Let a^{s_a} be a request a belonging to session s_a, waiting in a queue Q_k, $k \in \{1, 2\}$. We define the following sets and subsets of requests waiting in the queue Q_k at the n-th moment, when a new request belonging to session s appears:

$$Q_k(n) = \{a^{s_a} \in Q_k\}, \tag{3}$$

$$Q_{k\_2}(n) = \{a^{s_a} \in Q_k : P^{s_a}(n) \in \{2, 3, 4\}\}, \tag{4}$$

$$Q_{k\_3}(n) = \{a^{s_a} \in Q_k : (P^{s_a}(n) = 4)$$
$$\vee[(P^{s_a}(n) = 3) \wedge (v^{s_a}(n) \geq v^s(n))]\}, \tag{5}$$

$$Q_{k\_4}(n) = \{a^{s_a} \in Q_k : (P^{s_a}(n) = 4) \wedge$$
$$[(v^{s_a}(n) > v^s(n)) \vee [(v^{s_a}(n) = v^s(n))$$
$$\wedge(RFM^{s_a}(n) \geq RFM^s(n))]]\}. \tag{6}$$

The position number $z_k(n)$ in a queue Q_k, determined for a new request having arrived at the n-th

moment, is calculated according to the following formula:

$$z_k(n) = \begin{cases} |Q_k(n)| + 1, & \text{if } P^s(n) = 1, \\ |Q_{k\_2}(n)| + 1, & \text{if } P^s(n) = 2, \\ |Q_{k\_3}(n)| + 1, & \text{if } P^s(n) = 3, \\ |Q_{k\_4}(n)| + 1, & \text{if } P^s(n) = 4, \end{cases} \tag{7}$$

where $k = 1$ for an admitted HTTP request and $k = 2$ for a dynamic request, and $|\bullet|$ means cardinality of queue Q_k at the n-th moment. A pseudocode of KARO-Rev algorithm is presented in Fig. 3.

Algorithm KARO-Rev

```
1   if (a new HTTP request x_ip^s )
2       if (the request concerns an HTML file)
3           update session attributes: c^s(n), RFM^s(n), e^s(n), l^s(n), v^s(n);
4           update session priority P^s(n);
5           //admission control
6           if [((l_1 ≤ system_load < l_2)
7               and (P^s(n) == 1))
8               or ((system_load ≥ l_2)
9               andD ((P^s(n) == 1) or (P^s(n) == 2))]
10              reject the request;
11          else
12              accept the request;
13          end if
14      else //the request concerns an embedded object
15          accept the request;
16      end if
17      //scheduling in queue Q_1
18      if (the request has been accepted)
19          put the request into the queue Q_1 at the position determined
20          according to (7);
21      end if
22  else if (a new dynamic request y_jp^s )
23      //scheduling in queue Q_2
24      put the request into the queue Q_2 at the position determined
25      according to (7);
26  end if
```

Fig. 3. A pseudocode of KARO-Rev algorithm [4].

Simulation environment

The efficiency of a Web server system under KAR-Rev algorithm was verified by using a simulation-based approach. We designed and developed a simulation environment for B2C Web server system and used it to carry out experiments for different values of KARO-Rev parameters.

Our simulation tool consists of a session-based workload generator and a B2C Web server system simulator. The tool, system performance metrics, and a methodology for carrying out the experiments were presented in [8] in detail. The model of a Web server system and the way of request processing at the system resources were discussed in [9]. A detailed performance study of a Web server system under FIFO scheduling was discussed in [10].

In experiments presented in this paper *Typical* workload scenario was applied, emulating the most common workload conditions, when the user page latency limit is equal to 8 seconds and the percentage of key customers in the Web store is equal to 10.

We address the server system performance both in terms of "conventional" system performance metrics and the business-related ones. Performance metrics under consideration in the sensitivity analysis include the 90-percentile of page response time, the number of successfully completed sessions per minute, percentage of aborted *KC* sessions, revenue throughput, and potential revenue lost per minute (in dollars per second).

Simulated time of a single experiment included a 10-hour preliminary phase and the following 3-hour observation phase, during which the system performance was monitored.

Each simulation experiment was run for a constant number of new user sessions arriving at the site per minute (i.e. for the constant session arrival rate). The system performance was then presented as a curve on a graph for the session arrival rate ranging from 20 to 300 with a step of 20.

Parameters of KARO-Rev algorithm

Parameters of KARO-Rev algorithm may be divided into two groups: parameters related to e-business specificity and general parameters of the algorithm.

Business-related parameters

Business-related parameters are connected with RFM analysis and they have no direct impact on the computer system performance. When KARO method is used with a Web server system, each key customer of the Web store is characterized by three values of recency, frequency and monetary codes. Depending on the specificity of business conducted through the Web site, each of these components may be of different importance. It is the marketing strategy of the company which determines the choice of the corresponding weights w_R, w_F, w_M in (1), defining a *CVS* of a key customer. Due to unavailability of appropriate business data from real online retailers, we have assumed that all three weights are equal to 3, which gives *CVS* values ranging from 9 to 45. Such a range is large enough to differentiate between key customers themselves and allows evaluating relative levels of their QoWS without going into business-specific details.

In simulation experiments verifying the efficiency of KARO-Rev algorithm, at the beginning of each ex-

periment a database with a given number of key customers is generated. For each key customer a date of the last purchase, the total number of purchases and the appropriate sum of money spent in a Web store are generated. A five-year history of the customers' purchases in the Web store has been simulated. Numbers of purchases in the Web store vary from 1 to 75 and are generated regardless of the customers' last purchase dates. For each customer record in database, the sum of money spent by a customer is generated depending on the customer's number of purchases, where a product price ranges from \$5 to \$100.

After creating the customer database, a segmentation of key customer records according to RFM analysis is performed for a given date. In each simulation experiment the customer database and the resulting key customers' RFM scores are exactly the same. Table 1 summarized the business-related parameters.

Table 1
Business-related parameters of KARO-Rev algorithm.

Parameter	Values
Number of key customers in database	5000
Frequency code weight w_F	3
Recency code weight w_R	3
Monetary code weight w_M	3
Range of last customers' purchases [years]	5
Number of customer's purchases	1–75

General parameters

As opposed to the parameters related to RFM analysis, general parameters of KARO-Rev algorithm may directly affect its efficiency and in reality, they should be determined based on the analysis of Web traffic at a given e-commerce Web site. We chose their values based on our simulation model and results of preliminary simulation experiments (Table 2). A sensitivity of KARO-Rev to changes of AC thresholds and session length thresholds is analyzed in the next Section.

Table 2
General parameters of KARO-Rev algorithm.

Category	Symbol	Best value
AC thresholds [number of requests in Q_2]	I_1	30
	I_2	80
Session length thresholds [number of pages visited in the session]	T_{Med}	2
	T_{Low}	20
Queue timeouts [seconds]	T_1	8
	T_2	8

The indicator of system load intensity, $L(n)$, is the length of queue Q_2 at the n-th moment. The admission control thresholds, i.e. parameters I_1 and I_2,

determine two thresholds for the actual system load, used to take decision on the request acceptance or rejection (cf. Fig. 3). The best values of I_1 and I_2, determined based on results of simulation experiments discussed in the next Section, are 30 and 80 dynamic requests in Q_2, respectively. I_1 equal to 30 allows one to admit the adequate number of HTTP requests to protect the system from overload and prevent significant underutilization of its resources. I_2 is set to $I_1 + 50$ to clearly differentiate between QoWS levels for sessions with priorities 1 and 2.

The best values of session length thresholds, T_{Med} and T_{Low}, are equal to 2 and 20, respectively. They have been determined based on a user session model applied in simulation experiments and taking into consideration the way of determining the session priority according to (2). T_{Med} equal to 2 ensures a relatively small number of requests with priority 3 in the queues, and thereby it enables the site to give a relatively fast service to requests with priority 3 from unlogged key customers. Since the average length of an OC session is about 18 pages, a good value of T_{Low} is 20. As a result, priorities of OC sessions with empty shopping carts will be lowered from 2 to 1 only when the session length achieves 20, i.e. for really long OC sessions (probably generated by Web bots).

Values of queue timeouts, T_1 and T_2, after which a request will be dropped from queues Q_1 and Q_2, respectively, are both equal to 8 seconds. According to 8-second rule [11] this is the maximum latency tolerated by most Internet users.

Analysis of KARO-Rev parameters

In this section, the sensitivity of KARO-Rev algorithm to changes in its basic parameters is analyzed. In particular, the impact of different values of AC thresholds, I_1 and I_2, as well as session length thresholds, T_{Med} and T_{Low}, on business-oriented system performance metrics was analyzed.

Parameters I_1 and I_2 determine two thresholds for the length of the queue in front of the back-end server, $L(n)$, which is an indicator of the Web server system load intensity. Thus, their values affect a decision on HTTP request acceptance or rejection. Depending on these two parameters, the system load in a simulation experiment will be of different intensity. If these values are small, relatively many requests will be rejected at the Web server input. Consequently, the system will be well protected against overload, but its resources may be underutilized. On the other hand, if these values are high, much more requests will be accepted and then will compete for the use of

system resources. This may lead to longer page response times and a bigger number of aborted sessions due to exceeding the user page latency limit or the timeout defined for the queue in front of the back-end server, T_2. In order to study the sensitivity of KARO-Rev to AC thresholds, the influence of their various values on system performance is analyzed.

In all experiments in this group, values of the session length thresholds, T_{Med} and T_{Low} have been equal to 2 and 20, respectively. The experiments have been run for workload scenario *Typical*, for various combinations of the AC thresholds. After running preliminary experiments evaluating a relation between the mean number of dynamic requests in the back-end server and the mean number of aborted sessions in one second intervals, potential values of I_1 have been chosen. They varied from 20 (when some number of aborted sessions has just been observed) to 50, with a step of 10. Results for I_1 equal to 100 are presented as well, in order to evaluate the KARO-Rev system performance for extremely high AC thresholds and thereby under a relatively high system load. In all cases, I_2 has been equal to I_1 $+50$, to clearly differentiate QoWS levels for sessions with priorities 1 and 2. Values of parameters I_1 and I_2 in each experiment are denoted as a pair (I_1, I_2).

Figure 4 presents the 90-percentile of page response time as a function of the session arrival rate. As it can be seen, values of AC thresholds do have influence on QoWS measures connected with page response times provided by the system. The lower the AC thresholds, the lower the 90-percentile of page response time, because the overall system load is lower, mean lengths of the system queues are lower, and request waiting times are better.
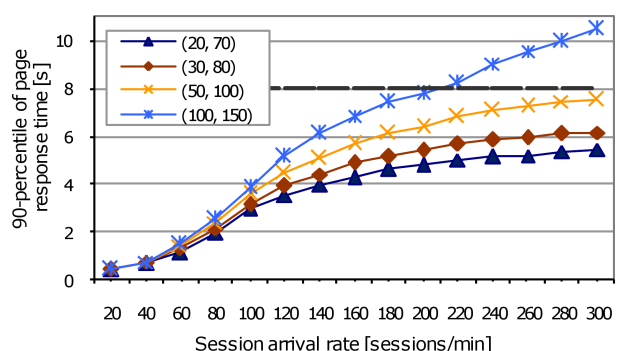

Fig. 4. 90-percentile of page response time for different AC thresholds.

The difference in the 90-percentile of page response time starts at the session arrival rate of 40 sessions/min and evidently increases with the increase in the system load. For the maximum load, 90% of Web pages have been processed within 5.4 seconds

for the lowest AC thresholds and within 10.4 seconds for the highest ones. The relation between the AC thresholds and page response times has been observed for the whole range of load intensity. However, it does not translate itself directly to other system performance measures, such as the number of successfully completed sessions per minute. As it can be seen in Fig. 5, lower AC thresholds lead to higher system throughput for very heavy loads (above the session arrival rate of 100 sessions/min), and to lower throughput for medium loads (for the session arrival rates of 40–80 sessions/min). It means that unless the system is heavily loaded, for low AC thresholds too many requests have been rejected at the system input, while there had been enough resources to effectively process some of them.
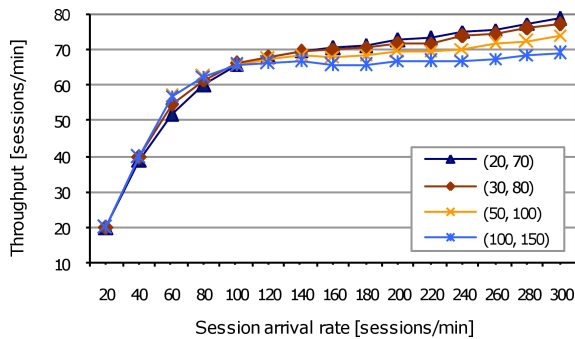
Fig. 5. Number of completed sessions per minute for different AC thresholds.

It is confirmed in Fig. 6, presenting a percentage session breakdown for different AC thresholds in two cases: for the session arrival rate of 80 and 300 sessions/min. Both for the moderately and heavily loaded system, the smaller number of sessions aborted due to admission control implies the bigger number of sessions aborted due to two other reasons: if request waiting times in the back-end server queue has exceeded timeout T_2 or if users had been waiting too long for responses and finally gave up. However, in both cases the impact of the AC thresholds on the number of successfully completed sessions is different.

Because the focus of our research is on system performance in terms of business-oriented metrics, we have examined which sessions had been aborted in the experiments for different AC thresholds, apart from why or where they had been aborted. The experiments demonstrated that values of the AC thresholds have no impact on the percentage of successfully completed *KC* sessions, which has ranged from 99.93 to 100% in all cases. However, they have impact on the amount of achieved revenue (Fig. 7), affecting the revenue throughput in a similar way as the system throughput in completed sessions but

to a significantly lower degree. As one can observe in Fig. 7, under very heavy load smaller values of the AC thresholds generally provide higher revenue throughput. However, under medium load, the least satisfactory results have been achieved for the case (20, 70), although for the case (30, 80) they have been very similar to the case (100, 150). In all cases, the KARO-Rev algorithm has been able to effectively cope with losses of potential revenue (Fig. 8) and to provide 99.3–100% of achieved potential revenue.
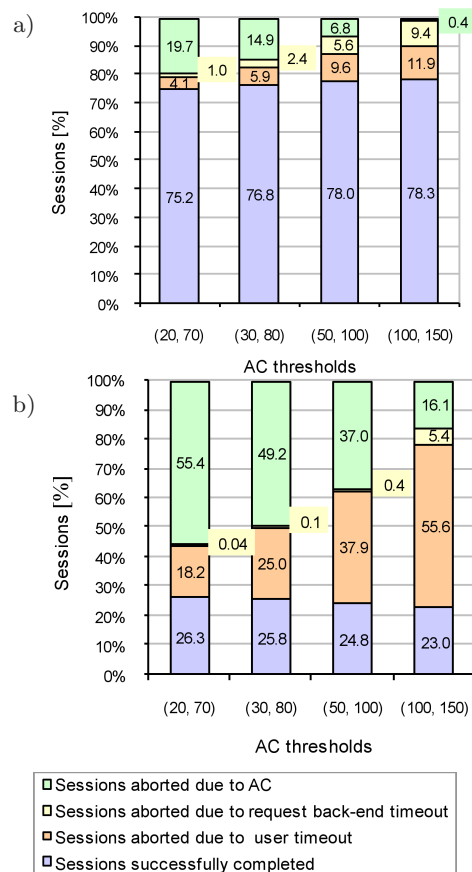
Fig. 6. Percentage session breakdown for different AC thresholds a) session arrival rate of 80 sessions/min, b) session arrival rate of 300 sessions/min.
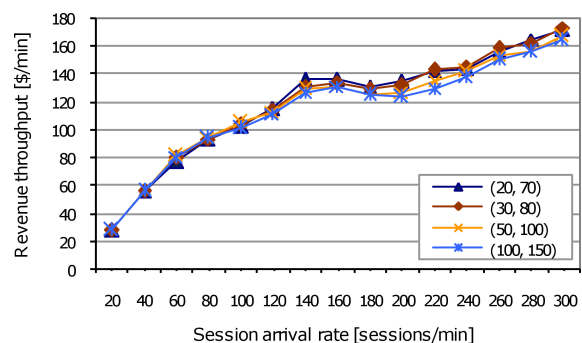

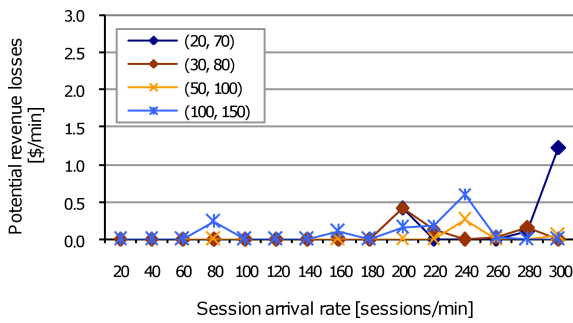Fig. 7. Revenue throughput for different AC thresholds.

Fig. 8. Potential revenue lost per minute for different AC
thresholds.

To sum up this part of analysis, the results have
shown that KARO-Rev is sensitive to AC thresholds values with regard to both conventional and
business-oriented performance metrics. The results
suggest it would be worth proposing a dynamic way
of adapting values of I_1 and I_2 to current system
load. We leave this issue to future work. The results
show that the values I_1 of 30 and I_2 of 80 are most
advantageous for KARO-Rev algorithm.

Session length thresholds

Parameters T_{Med} and T_{Low} determine two
thresholds for the session length (i.e. the number of
Web pages visited in a session), at which the priority of an OC session with an empty shopping cart
will be lowered from 3 to 2 and from 2 to 1, respectively, according to (2). Values of these thresholds
influence especially the number of OC requests with
3 and 2 priorities in the system. Thus, they also affect response times of requests from unlogged key
customers, and may affect the amount of achieved
revenue as well. That is why the sensitivity of KARO-Rev to the session length thresholds is evaluated.

Experiments in this group were performed for the
Web server system under control of KARO-Rev algorithm for *Typical* workload scenario and for various
combinations of the session length thresholds. In all
the experiments, I_1 and I_2 have been equal to 30 and
80, respectively. Values of the session length thresholds, T_{Med} and T_{Low} in each experiment are denoted
as a pair (T_{Med}, T_{Low}).

First, the impact of the first session length threshold, T_{Med}, on business-oriented system performance
metrics has been analyzed. Corresponding experiments have been run for different values of T_{Med} and
a fixed value of T_{Low} equal to 20, which is a little bit
more than the average length of an OC session.

It has to be noticed, that all new sessions receive
priority 3 – when users enter the home page of the
site – and at that time key customers are not logged
on yet. That is why requests with priority 3 from unlogged key customers and from ordinary customers

with empty shopping carts are treated exactly in the
same way – they are queued after requests with priority 3 from ordinary customers with not empty shopping carts. For that reason, all requests with priority
3 should be processed relatively quickly, to enable
key customers to get service in reasonable time and
log into the site. The smaller the value of T_{Med} is,
the less OC sessions with priority 3 there are, and
thereby better service is experienced by all requests
with priority 3.

In the applied workload model, all key customers
log on just after entering the site, i.e. when the session length is equal to two. That is why we set the
initial value of T_{Med} of 2 in the experiments. In this
case, OC sessions will be moved to priority 2 very
quickly, and the number of requests with priority 3
in both queues, Q_1 and Q_2, will be relatively small.
In successive experiments, the value of T_{Med} has been
augmented by 2, up to 8.

Figures 9 and 10 plot the amount of revenue
achieved and lost per minute, respectively, for different values of T_{Med} as a function of the session arrival
rate. As it can be seen, for the extremely heavy loaded Web server system (corresponding to the session
arrival rate of above 200 sessions/min), bigger values of T_{Med} imply lower revenue throughput, while
potential revenue lost per minute is not clearly dependent on T_{Med}. For the maximum offered load, the
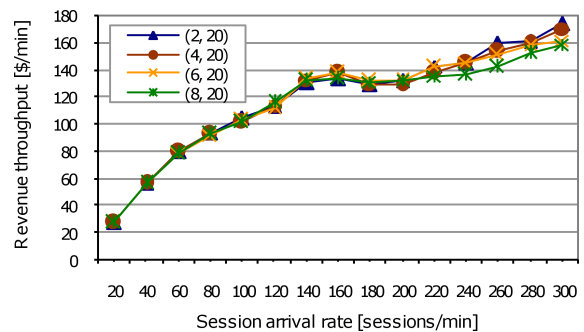difference in the revenue throughput for two extreme
cases has been about \$15/min.

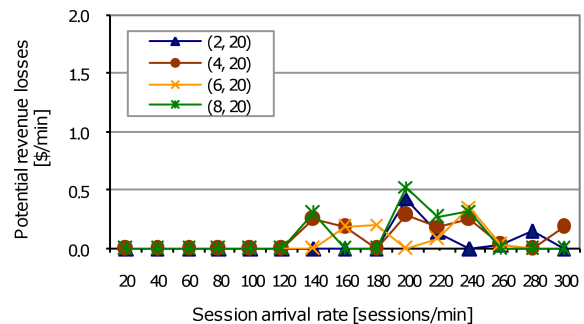Fig. 9. Revenue throughput for different values of T_{Med}.

Fig. 10. Potential revenue lost per minute for different
values of T_{Med}.

As it can be seen in Fig. 11 and Fig. 12, lower revenue throughput in the case of higher T_{Med} has been caused mainly by the significantly more KC sessions aborted due to long page response times, either due to the back-end server queue timeout or due to the user patience timeout. The bigger T_{Med}, the more requests with priority 3 from OC sessions and thus, the higher page response times for sessions with priority 3 (including KC sessions at the earliest stage). Consequently, more KC sessions were aborted and less key customers had a chance of logging into the site and being promoted to priority 4. As a result, adequately less products could be added to KC shopping carts, and smaller amount of potential revenue could be turned into the achieved revenue. As it can be seen in Fig. 11, for the maximum offered load, the percentage of aborted KC sessions has varied from 0.02 for $T_{Med} = 2$ to 13.35 for $T_{Med} = 8$. On the contrary, the percentage of aborted OC sessions has appeared to be independent of the first session length threshold and in all cases has been about 84% (not shown).
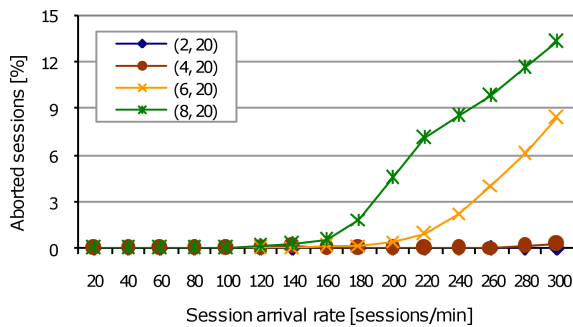
Fig. 11. Percentage of aborted KC sessions for different values of T_{Med}.
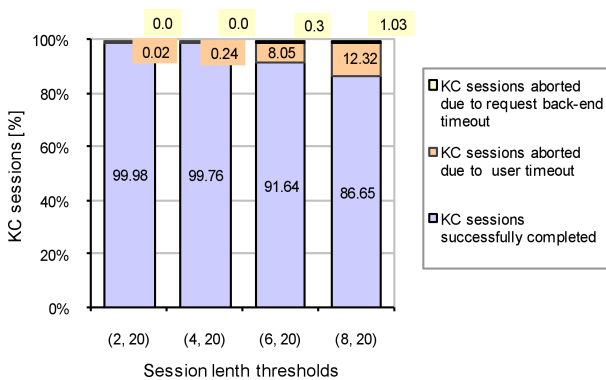
Fig. 12. Percentage KC session breakdown for different values of T_{Med}, for the session arrival rate of 300 sessions/min.

After evaluating the impact of the first session length threshold on the system performance in terms of business-oriented performance metrics, similar experiments for the second session length threshold have been performed. The experiments have been run for different values of T_{Low} and a fixed value of T_{Med} equal to 2.

Figures 13 and 14 show that the amount of revenue achieved and lost per minute do not depend clearly on the value of T_{Low}. There have been small differences between the corresponding metrics for individual session arrival rates, but one cannot observe their dependence on T_{Low}. Similarly, there has been no relation between T_{Low} and the percentage of successfully completed KC sessions, which has been rather stable and has varied from 99.95 to 100. The value of T_{Low} has only a little impact on the percentage of successfully completed OC sessions (not shown). For the session arrival rates of 60–120 sessions/min, smaller values of T_{Low} imply a bit higher values of this percentage, but the difference does not exceed 3%.
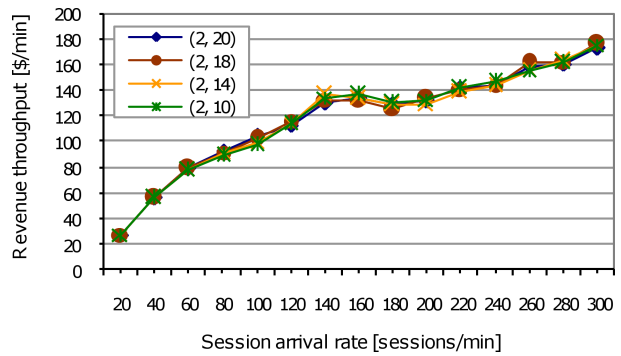

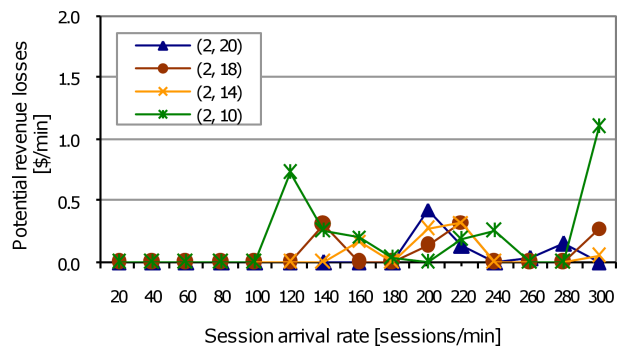Fig. 13. Revenue throughput for different values of T_{Low}.

Fig. 14. Potential revenue lost per minute for different values of T_{Low}.

To sum up this part of analysis, KARO-Rev has turned out to be insensitive to the value of the second session length threshold, T_{Low}, in terms of business-oriented system performance metrics. However, the algorithm is sensitive to the value of the first session length threshold, T_{Med}, especially under system overload. For the applied model of a KC session at the B2C site, T_{Med} equal to 2 has led the system

to achieve the highest revenue and to offer the best QoWS for key customers. Therefore, we can say that values T_{Med} of 2 and T_{Low} of 20 are most advantageous for KARO-Rev.

In reality, the choice of T_{Med} should be made based on the analysis of key customers' navigational patterns at a given B2C Web site. If most of key customers log on at the very beginning of their sessions (like in our workload model), a very low value of T_{Med} will be a good choice. However, if most of them log on later, higher values of this threshold would probably be better and would prevent the system from lowering the priorities of unlogged key customers' sessions too early.

Conclusions

Simulation results discussed in the paper have shown that the proper adjustment of KARO-Rev parameters may be significant with regard to business-oriented and conventional performance metrics. The results suggest that applying the algorithm in a real-life B2C Web site should be preceded by the analysis of key customers' navigational patterns at the B2C Web site to tune the session length thresholds, T_{Med} and T_{Low}, to turn more visitors into customers. Moreover, it seems to be worth working out a dynamic way of adapting values of the AC thresholds, I_1 and I_2, to the current load of the Web site.

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VALUE ENGINEERING APPLICATIONS FOR MANAGING SUSTAINABLE INTERMODAL TRANSPORTATION INFRASTRUCTURE ASSETS

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ABSTRACT
Frequent gridlocks and traffic jams during the periods of rush hours can result in long user delays and more vehicle emissions causing continuous degradation of air quality. The built-infrastructure of densely populated cities and intercity travel by passenger and freight traffic lead to significant adverse impacts of traffic congestion on air quality, greenhouse gas emissions, and global warming. Transportation contributes 28% of energy related greenhouse gas emissions in the U.S. This paper shows that traffic related carbon dioxide (CO_2) emissions are higher per capita for several rural and smaller cities compared to large urban areas in the United States. Inadequate use of mass transit, urban sprawl, construction of more roads and traditional stop-controlled intersections, and addition of more lanes to increase traffic capacity and ease congestion, are primary causes of significant vehicle emission inventory of CO_2 and air quality degradation. It is shown that sustainable traffic management policies, such as reduction of work-related travel by cars and more use of mass transit modes, can decrease CO_2 emissions. Case studies of value engineering applications are presented to select cost-effective less polluting mass transport strategies based on economic evaluation of life cycle costs and benefits.

KEYWORDS
Economic Evaluation, Infrastructure Assets, GHG Emission, Socio-economic, Sustainable, Transportation, Life Cycle, Mass Transit, PRT, Value Engineering.

Introduction

Roles of cities and intermodal transport for sustaining socio-economic growth

The efficient public mobility, workplace commute, delivery of goods, access to consumer services, creation of new businesses, job growth, and emergency management during disasters, all depend on efficient and safe transportation infrastructure assets [1]. Similarly, freight traffic and global supply chain inventory management system stakeholders depend on a smooth seamless flow of freight through interconnecting shipping ports, airports, rails, and roads. A recent report by the National Academies [2] shows

that U.S. companies collectively spend a trillion dollars a year on freight logistics. This is nearly 10% of the nation's Gross Domestic Product (GDP). The report states that considering that about 80% of the population works and lives in cities and urban areas in the U.S, 65% of goods originate or terminate in cities as per a recent commodity flow survey by the U.S. Department Of Transportation (DOT) [2]. These statistics are indicative of the contribution of cities and importance of the lifeline supply chain to support our society and daily life.

This built-environment of cities and inter-city transport infrastructure leads to significant adverse impacts on traffic congestion and air quality, Green House Gas (GHG) emission, climate change, and nat-

ural disaster hazards on urban sustainability, mobility, and quality of life. The environment and energy resources are greatly impacted by growth of cities and landuse practices, transportation system planning, managing travel demand and traffic operations, and modal share of trips. Anthropogenic CO_2 emission is a major contributor to GHG and global warming. Transportation contributes 28% of energy related GHG emissions in the U.S. As of 2007 the U.S. transportation sector included over 254 million road transport vehicles which comprised of 93.3% cars and other automobiles, 2.8% motorcycles, 0.3% buses, and 3.6% trucks [3]. However, trucks on average travel almost twice as much as cars per vehicle per year, consume 3–4 times more fuel than cars per vehicle, and produce both harmful pollution and GHG emissions, as shown by modal comparison in Fig. 1. Freight trucks produce six times more pollution than freight rail (Fig. 2). The growth in passenger travel, freight demand, and traffic congestion directly contributes to increases in mobility costs, user operating costs, air pollution and GHG emissions, public health costs, and other societal costs. Congestion also causes wastage of fuel and stress on commuters.

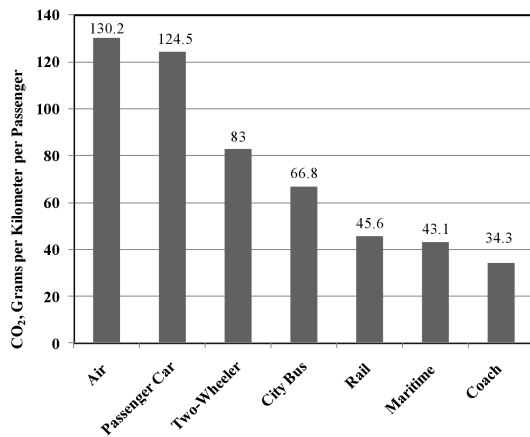(Data credit: European Environment Agency/Allianz, SE)

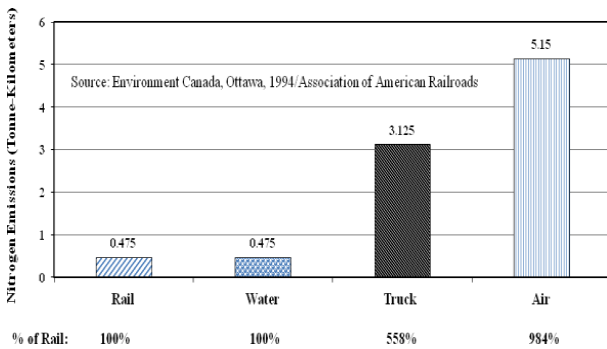Fig. 1. Modal comparison of passenger transport emissions.

Fig. 2. Modal comparison of freight transport emissions.

Objective

The primary objectives of this study are to:

(1) Review congestion issues in cities and urban areas, transportation related GHG emission concerns, and air quality impacts.

(2) Demonstrate effectiveness of value engineering approach to evaluate life cycle costs and benefits for justifying less polluting sustainable intermodal transport infrastructure management strategies in cities and metropolitan areas.

Needs for sustainable intermodal transport management

Since the industrial revolution, the world population has been continuously urbanized as people migrate from rural areas to cities. About 80% of the current population in industrialized countries lives in densely populated cities and metropolitan areas occupying a very small fraction of the available land area. The developing countries are showing similar trends with 50% population in cities and more megacities are now outside North America and Europe. With good governance, cities can deliver economic growth, education, health care and other services more efficiently than less densely populated rural areas simply because of their advantages of scale and proximity of infrastructure and job market. Cities also present opportunities for social mobilization, women's empowerment, and cultural diversity. Moreover, higher density of urban populated areas can relieve pressure on surrounding natural habitats and areas of biodiversity if sustainability goals are given priority in infrastructure asset management and transportation planning. The challenge in the next few decades for the future of society depends on learning how to exploit the economic and social benefits urbanization offers without adverse impacts on the environment, which requires developing and implementing sustainable landuse and transport management policies.

Between 1990 and 2007 the U.S. inventory of anthropogenic GHG emission included electricity, transportation, industrial, agricultural, residential, and commercial sectors. The transportation sector accounted for 28% of all anthropogenic GHG emissions in the U.S. trailing the electricity sector (34%), followed by industrial (20%) and agriculture (11%) sectors [4]. On-road vehicles contribute 81% of all transportation related GHG emissions in the U.S. in 2004 that increased to 84.5% in 2008 (Fig. 3). Roads represent the dominant mode of inland traffic in most countries and carry most of the passenger traffic and freight traffic. The deficiency of road infrastructure assets and traffic demand exceeding road capacity

pose significant challenges to traffic safety and traffic flow management in many cities of developing countries. Frequent congestions and transportation choke points in most urban areas and cities are adversely affecting travel time, business operating costs, and air quality. It is estimated that 75% of all GHG emissions worldwide are produced by cities and one-third of this is from transportation sources [5]. Increased air pollution (particulate matter particularly) is affecting public health, especially in terms of increase in respiratory diseases and higher mortality rates.
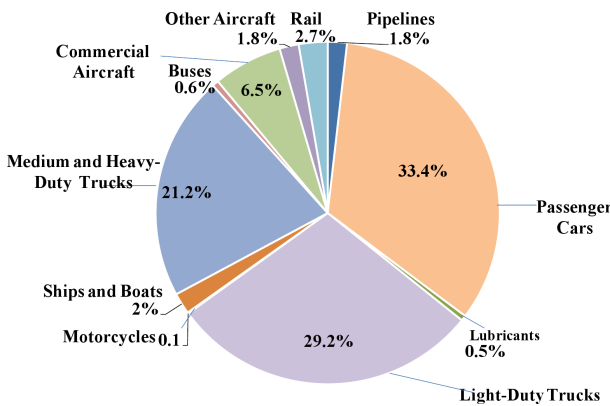
Fig. 3. GHG Emission by Transportation Mode, 2008. (source: US Environmental Protection Agency, 2010).

The measure of the amount of CO_2 released, as well as other vehicle emissions, is dependent on traffic demand, driving patterns, traffic flow, congestion hours, vehicle-miles traveled, traffic speeds, and vehicle characteristics. Figure 4 shows that road traffic related emission is higher per capita for several rural and smaller cities compared to large metropolitan areas in the United States and other megacities in developing countries [5].
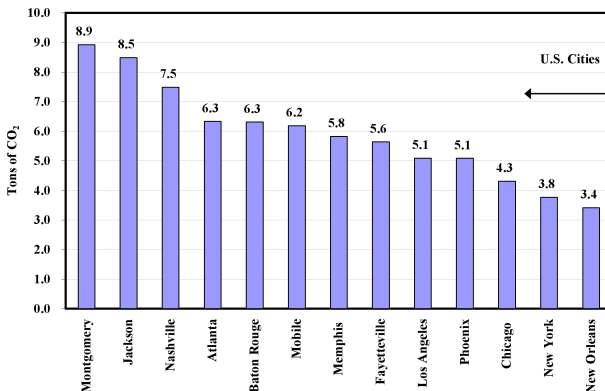

Fig. 4. Annual Per Capita CO_2 Emissions from Road Traffic in Selected U.S. Cities for 2007.

A metropolitan area includes both urban area and rural area that are socially and economically in-

tegrated with a particular city. Urban sprawl in both metro and non-metro cities destroys parks, agricultural land, forestland, and open spaces. Additionally, it leads lots of city population at risks of flood and other natural hazards. Furthermore inadequate use of mass transit, increasing urban sprawl, deforestation, building more roads and intersections, and adding more lanes to increase capacity and ease congestion are primary causes of increased vehicle emissions of CO_2 and air quality degradation.

Sustainability goals and traffic management challenges for cities and intercity travel

Sustainability is broadly defined as a preservation, development, and traffic management measure that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability goals with respect to intercity travel of people and freight, city infrastructure, and the environment are:

• Enhancing health, Safety and Security;
• Conserving Energy and Enhancing the Environment;
• Creating Equitable and Livable Communities;
• Promoting Economic Prosperity.

Table 1
GHG Emissions by Mode of Transportation in the U.S., 1990–2004 (Source: Transportation Research Record 2017, The National Academies, Washington, DC).

Transport Mode	Travel and GHG Emission Indicators	% Change
Road – Light Duty Vehicles (cars and trucks)	Vehicle Miles Traveled (VMT)	+37%
	Fuel Efficiency (offset by VMT)	+4%
	GHG Emissions	+23%
Road – Heavy Duty Vehicles (freight trucks)	Vehicle Miles Traveled (VMT)	+53%
	Truck Ton-Mile Increased	Yes
	GHG Emissions	+62%
Aviation – Commercial Aircraft	Air VMT	+64%
	Passenger Load Factor	+14%
	GHG Emissions	+10%
Rail (Non-Road)	GHG Emissions	+32%
Water-borne	GHG Emissions	+25%
Pipeline	GHG Emissions	+0%

Dependence of commuter mobility and freight truck on fossil fuel consumption is definitely not sustainable. Travel demand (number of vehicles and vehicle-km traveled) is at its highest level. Energy demand is also at its highest level. Fossil fuel sources are diminishing, greenhouse gas emissions are reaching to an extremely high level, and migration from rural areas to urban areas and mobility needs are

all accelerating these adverse impacts on the environment. Table 1 shows significant increase in road traffic indicators and associated GHG emissions compared to other transport modes. Due to significant fuel efficiency in modern aircraft aviation emission dropped to $1/6^{th}$ of heavy-duty freight trucks.

In 2003, congestion in the top 85 U.S. urban areas caused 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel, for a total cost of $63 billion [6]. An average of 15 gallons fuel was wasted per person and 25 hour delay per person per year was contributed due to congestion in 2003.

There is a strong need to implement sustainable transportation management policies for reducing dependence on fossil fuel, resulting emissions, congestion, and crashes [7].

It is evident that a reduction of work-related travel by deploying mass and public transit can remove thousands of single occupancy vehicles from roads during peak hours and decreases CO_2 and other vehicle emissions in cities. Integrated intermodal transport management strategies to reduce single occupancy vehicles on roads in cities include underground and surface electric powered track-based metro integrated transit buses. As shown in Fig. 5, 132 cities worldwide have implemented metro transport infrastructure networks and/or are expanding their metro networks [8]. This figure shows that 23 cities have 0.5 million or more people riding metro systems annually.
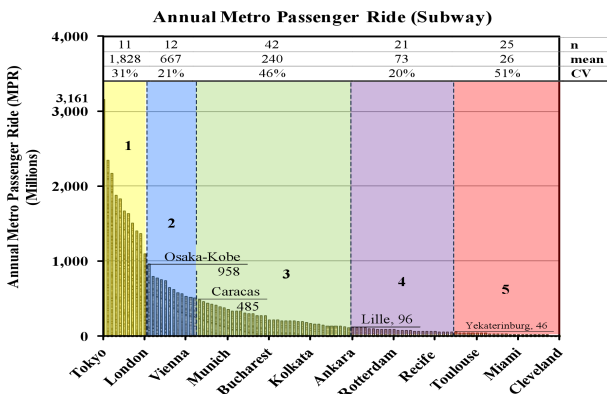

Fig. 5. World Annual Metro Passenger Ride in Million.

Table 2 shows selected 16 cities ranked in descending order from the highest annual metro ride in millions. The Tokyo Subway and Moscow subway systems are the top two most highly used rapid transit system in the world. Moscow, Hong Kong, and Guangzhou are the top three cities with the largest % of population riding metro [8]. Only two American

cities of New York and Washington DC are listed in the table. New York City has 22.6% of 19.4 million population who rides the metro.

Table 2
World's Selected 16 Cities Ranked in Descending Order from The Highest Annual Metro Ride.

Rank	City, Country (Annual metro ride)	%Pop.
1.	Tokyo, Japan (3,161 million)	23.6
2.	Moscow, Russia (2,348 million)	61.0
3.	Shanghai, China (1,884 million)	31.1
4.	Beijing, China (1,840 million)	40.7
5.	Guangzhou, China (1,640 million)	50.6
6.	New York City, USA (1,604 million)	22.6
7.	Paris, France (1,506 million)	39.4
8.	Mexico City, Mexico (1,410 million)	20.0
9.	Hong Kong, China (1,366 million)	53.0
10.	London, UK (1,107 million)	35.1
11.	São Paulo, Brazil (754 million)	10.2
12.	Singapore (745 million)	42.2
13.	Delhi, India (460 million)	5.7
14.	Washington, DC, USA (217 million)	13.3
15.	Bangkok, Thailand (64 million)	2.5
16.	Istanbul, Turkey (56 million)	1.5

Most other American cities show relatively low metro ridership considering their large populations. However, Moscow metro ridership constitutes the highest at 61% of 10.5 million population. This indicates a large network of metro system in Moscow with most people using it. Moscow and Tokyo are good examples of sustainable clean mass transit, which lead to smaller carbon footprint per capita in these cities.

São Paulo metro administration in Brazil has embarked upon a traffic management plan to provide fossil fuel-free mass transit transport to its citizen within five years. This plan includes expanded metro subway lines, mono rail line, ground rail line, dedicated bus rapid transit road lanes, and privately owned networks of bus lines [8]. This is the only example of an integrated intermodal transport network in the world where commuters buy one electronic ticket that can be seamlessly used in any one of these modes.

These sustainable and efficient transportation management practices provide clean, sustainable, and safe mobility needs in large cities. Most past transportation projects and city planners did not fully consider the interaction of transportation infrastructure planning with the landuse planning & built environment and their adverse impacts on air quality and GHG emissions.

Managing transportation systems

Life cycle or "whole life" approach

Life cycle or "whole life" approach was used first time in the 1997 pioneering book *Infrastructure Management System* by Hudson, et al. [9]. This approach integrates design, construction, renovation and life cycle maintenance phases of physical systems serving the society including transportation infrastructure assets. Figure 6 shows why life cycle assessment is important considering in-service life has the largest influence on life cycle infrastructure costs [9], which will be even higher if non-sustainable transport assets are promoted with respect to vehicle emissions.
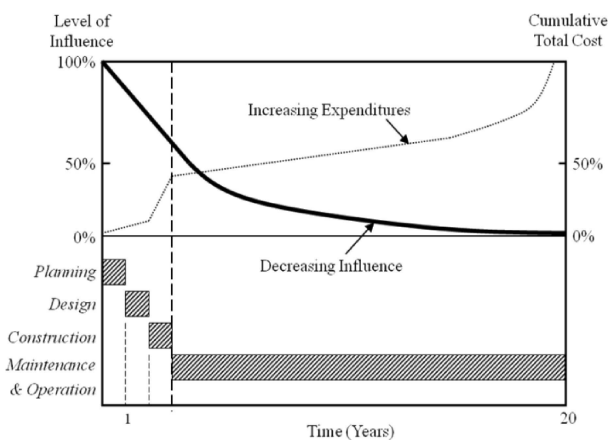

Fig. 6. Influence Levels of Life Cycle Phases on Total Infrastructure Costs.

It is recognized that initial construction costs of track-based underground or elevated electric powered mass transit infrastructure and their integration with intermodal transit transport strategies are several times higher compared to initial construction costs of traditional road transport infrastructure. However, these innovative mass transit assets can be justified based on life cycle cost and benefit comparisons through value engineering approaches because they need less annual maintenance and four times more service life than road infrastructure without any major repair/reconstruction. Also, these electric powered track-based transit services emit zero emissions and are relatively safer than road traffic.

Accounting approach of asset management

The U.S. Governmental Accounting Standards Board (GASB) initiated a first comprehensive look in 1984 at accounting and reporting of government owned public infrastructure/fixed assets. The GASB 34 statement (GASB 34) promulgated on June 15, 1999 [10] that financial reporting does not require

government owned long-lived public infrastructure assets to be depreciated if the assets are:
- Managed using an infrastructure asset management system;
- Preserved at an established condition level.

GSB 34 standard for valuation of public capital assets in the U.S. was implemented by the U.S. DOT Federal Highway Administration (FHWA) for reporting of transportation infrastructure asset valuation and condition [10]. Since the implementation of GASB 34 standards in the 21st century by U.S. highway agencies and municipal public works agencies, emphasis on documenting and reporting of financial/accounting information has been placed. Figure 7 shows GASB valuation framework of infrastructure asset management [after 10]. It requires that an infrastructure asset management system should include an inventory of assets and condition assessment at least every three years. The results of the three most recent assessments should show that the infrastructure assets are being preserved at or above the established condition level.
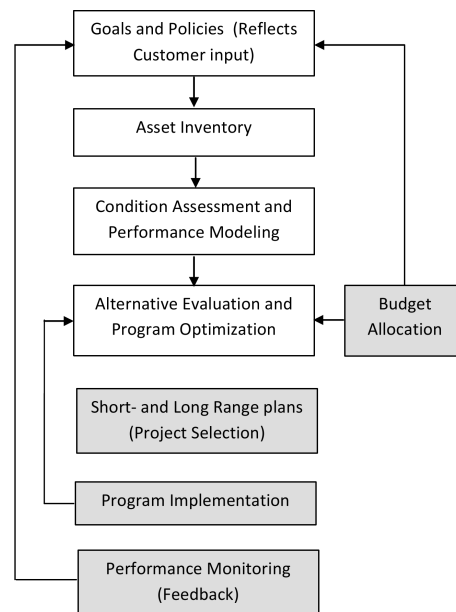

Fig. 7. A General Asset Management Framework. Adapted from Asset Management Primer, Federal Highway Administration, 2000 [10].

Sustainable infrastructure asset management

Increasing energy demand, diminishing natural resources, raising air pollution, growing GHG emissions, and preserving the environment are current issues of public awareness and general concerns worldwide [5]. Sustainability takes a center page in terms of reducing GHG emission after the 1999 Kyoto Pro-

tocol and subsequent international accords. The latest accord on June 19, 2012 in Rio de Janeiro eventually endorsed a global plan of action for sustainable development and transportation. The sustainability emphasis is not considered in the infrastructure asset management discussed in the preceding section. Metro and other mass transit modes produce less emission than cars and are, therefore, more sustainable. Asset management considering sustainability dimensions are discussed in detail by Uddin et al. [11].

Value engineering analysis

Basic principles and overview

Value Engineering (VE) enables to evaluate a cost-effective management strategy by selecting alternative technologies and methods to achieve reduction in overall life cycle costs without compromising safety and functional performance. Originally implemented by General Electric and defense industries in early 1950's in the U.S., VE has been used to implement innovative materials and methods, reduce cost, and enhance efficiency by manufacturing and production engineering entities. The VE implementation by FHWA is the U.S. started in early 1970s, as summarized by Jackson [12]:

- After VE section was included in Title 23, FHWA initiated VE training program for state highway agencies in 1973–1975.
- National Highway System (NHS) Act of 1995 mandated VE review for all NHS projects costing over $25 million. FHWA's VE regulation implementing law was published February 14, 1997 and a VE program was established to study NHS projects costing more than $25 million.
- The 2005 surface transportation legislation of SAFETEALU (Safe, Accountable, Flexible, Efficient Transportation Equity Act – A Legacy for Users) mandated:
  - State shall provide a value engineering analysis for each project on the Federal-aid system with an estimated total cost of $25 million or more.
  - A bridge project with an estimated total cost of $20 million or more: and
  - Any other project the Secretary determines to be appropriate.
  - Contractors were allowed to propose innovative alternative materials and methods through Value Engineering in Construction Project (VECP) studies.

Accomplishments of VE projects in the U.S. are summarized in Table 3 for federal Fiscal Year (FY) 2005 [12].

Table 3
FHWA's VE Project Accomplishments, 2005.

Item	NHS	Florida
No of VE studies	298	3
Cost of VE studies	$9.42 Million	$0.05 Million
Total project cost	$31.5 B	$14 Million
Total # of recommendations	2244	62
Value of recommendations	$6.7 Billion	$5.8 Million
Approved recommendations	917	1
Value of approved recommendations	$4.9 Billion	$1.3 Million
Value of approved VECP projects	$37.3 Million	$0.01 Million

The VE approach examines all potential cost items for identifying measures that can reduce life cycle costs without compromise to the function of the item (s) and safety. According to Pareto's law 20% of the items make up 80% of the total cost (Fig. 8) which can help to identify construction items for alternative materials.
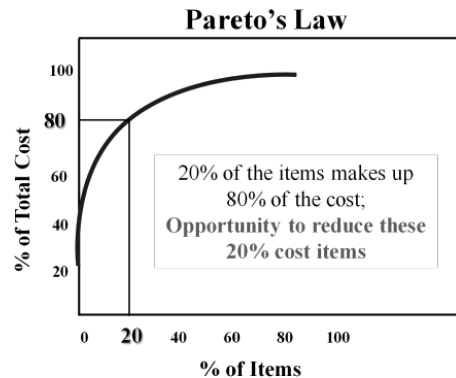

Fig. 8. Illustration of Pareto's Law [after 12].

Some innovative materials and methods first proposed in the VE studies have been accepted in practice. An example is the use of polymeric Fiber Reinforced Plastic (FRP) sheet piles instead of traditional concrete sheet piles by the Florida DOT to protect coastal roads from hurricane destruction (Fig. 9), first presented in the 2006 VE workshop [13].

Installation of innovative non-corrosive lightweight polymeric FRP sheet piles is easier and 3–4 times faster than concrete sheet piles. Based on the results of a value engineering study the overall cost was reduced by one-third. The FRP sheet pile, as an alternative to traditional concrete sheet pile, has been adapted in the design standards of the Florida DOT and many local government agencies in Florida.
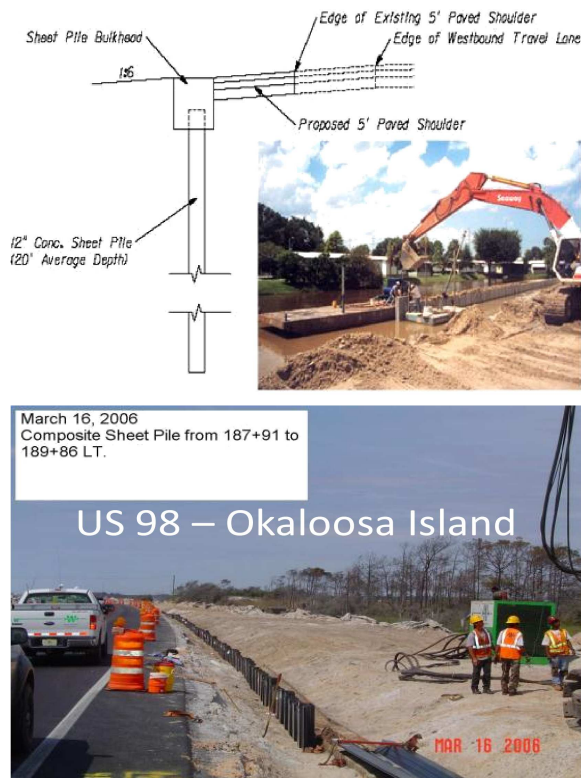
Fig. 9. Traditional Concrete Sheet Piles (top) and FRP Sheet Pile (bottom) Installation (credit: Florida DOT, Kurt Lieblong 2006).

The goals and concerns of VE analysis of infrastructure project designs before bidding and contracting are:
- VE must consider a reduction in overall costs while satisfying all required functions of the project and safe operation.
- VE must show benefits to the users and public.
- VE must minimize adverse environmental, user, and societal impacts.

The economic evaluation requires LCA of cost and benefits for a chosen analysis period for all competing alternatives identified for one or more assets in the VE process of design review.

Life Cycle Assessment of Costs and Benefits

The major initial and recurring costs over the life cycle that a public agency may consider in the Life Cycle Assessment (LCA) of project alternatives include the following:
- Ownership and operating/maintenance costs (agency costs);
  - Engineering and administration costs;
  - Initial capital costs of construction;
  - Future costs of maintenance, rehabilitation, and reconstruction;

  - Cost of maintenance and protection of traffic;
- Salvage return or residual value at the end of the period ("negative cost");
- Costs of borrowing (for projects not financed from allocated public funds or toll revenues);
- User costs related to service interruptions and time delays;
- Pricing/service costs.

The following benefits are traditionally considered in LCA calculations:
- Benefits in terms of additional taxes or total revenue generated;
- Reduction in service interruption costs;
- Direct reductions in life-cycle costs.

Additionally, the following societal benefits can be considered if sustainability goals are considered in infrastructure investment decision-making process.
- Reduction in congestion, waste of fuel, and air pollution;
- Reduction in GHG and other harmful emissions;
- Reduction in air pollution related public health medical costs;
- Reduction is lost productivity due to emissions and smog;
- Societal savings due to a reduction in carbon surcharge cost.

Emission related public health impacts resulting from urban energy consumption and transportation assets are significant. The related public health costs are significantly higher than typical road user and non-user costs traditionally used for evaluating alternative transportation strategies. Reducing congestion will result in reduction of wastage of fuel. However, life-cycle benefits are large from such savings. As a result, sustainable transportation policies enhance socio-economic prosperity, investment decision-making, public health, and the environment. These societal benefits are especially important if innovative intermodal integration strategies are considered for cities and intercity transport infrastructure for the purpose of achieving goals related to sustainability and reducing adverse impacts of single occupancy vehicles on the environment.

The LCA for a given analysis period is conducted as present worth analysis by discounting the life-cycle costs and benefits to the present value of dollars. Two different present worth factors used in the combined LCA equation; one to discount a single future amount and the other to discount a series of annual future amounts to present worth.

Example: The present worth life cycle cost (P) of a public transit bus project will acquire buses for a service life of (n) years, with an initial cost (C), a

yearly maintenance cost (M), and a salvage value (S) is equal to:

$$P = C + M \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] - S \left[\frac{1}{(1+i)^n} \right], \quad (1)$$

where C – Initial bus fleet cost = $1,000,000 for 10 buses (at $ 100,000 per bus), M – Maintenance costs = $3,000/per year, S – Salvage value = $200,000.

Assume an analysis period (n) of 10 years and an annual discount rate (i) of 5% to calculate present worth.

P = 1,000,000 + 3,000 (7.72217) – 200,000 (0.6139),

P = 1,000,000 + 23,165 – 122,780,

P = $ 900,385 (present worth of all life-cycle agency costs).

Similarly, present worth benefits (B) of the bus option can be calculated over 10 years, which will include annual bus fare revenue. The benefit-cost ratio (B/P) is one way of ranking the alternatives where the alternative with the highest ratio is given top rank. Net Present Value (NPV) is another way of ranking alternatives where NPV is the difference of B and P, which is used to rank alternatives from the highest to the lowest NPV value.

Transportation management strategies to mitigate traffic congestion and emission engineering analysis

Sustainable Transport Infrastructure Solutions

Uddin [5] suggests several transportation management strategies for achieving goals of sustainable transport infrastructure, which include the following:
- Reducing congestion, user delays, and wastage of fuel in queues.
- Improving mobility using multimodal approach as a part of space planning concept.
- Using transit modes operating on alternative less polluting energy.
- Increasing mass transit mode share by increasing car parking prices.
- Improving traffic flow management using video surveillance and other Intelligent Transportation System (ITS) technologies to reduce gridlocks, delays, and emissions.
- Evaluating and implementing less polluting and more efficient rail and pipeline solutions for freight transport in place of current dependence on highway trucks. The diesel gulping trucks are highly polluting and emit several times more GHG emissions than alternative freight rail mode. This strat-

egy will also require the construction and management of intermodal facilities.
- Increasing revenues by collecting higher fuel taxes on gasoline and diesel.
- Creating new financing opportunities by collecting transportation related carbon emission tax from trip makers by providing incentives of no such tax for commuters who predominantly use transit.
- Constructing more green spaces and promoting non-motorized cycling and pedestrian walking.
- Monitoring air quality and striving for less air pollution and clear skies.
- Reducing backlog of infrastructure and preserving state of good repair.
- Serving more people and creating/preserving jobs.

Atlanta Case Study for Citywide Pollution Mitigation Efforts

The Georgia Department of Transportation (GDOT) implemented Travel Demand Model (TDM) in Atlanta, Georgia, which has been a nonattainment urban area for many years due to higher level of air pollution. The success of its program in reducing congestion and GHG emissions is due to the use of reliable performance metrics to pitch its messages to the public [14]. For example, the Clean Air Campaign (CAC), a not-for-profit corporation that was formed in 1996 by collaboration of government, business, and civic organizations [14]. The CAC began to conduct employer outreach in 2000 by focusing on travel behavior through informed decisions and public education campaigns. The most effective TDM marketing programs involve a variety of partners within a community, including public officials, community organizations, and individuals support transportation alternatives. Through community based TDM efforts transport network in Atlanta metro area boasts a significant annual reduction in pollution and other benefits each year [14]:
- 16 Million car trips eliminated from metro Atlanta roadways;
- More than 200,000 tons of pollution not released into the air;
- More than $156 million estimated in reduced commute costs;
- $30 million estimated in health related costs savings due to improved air quality.

New York City's Sustainability Management Initiatives

New York City, leading by example, set public policy goals to reduce citywide carbon emissions by 30 percent below 2005 levels by 2030 [15]. Table 3

compares CO_2 equivalent (CO_2e) per capita emission for several U.S. cities and London. The City is making concentrated effort to reduce transportation emission that in 2005 represented 23% of total emissions. Total auto trips transport 55% of people using motorized transport mode, contribute to 78% of transportation emissions, and generate 18% of overall CO_2e. The City is promoting mass transit, bike lanes, and alternative fuel vehicles to reduce auto trips, as well as other sectors.

Table 4
Comparison of New York City's GHG Emission Footprint
with Other Cities, 2005 [15].

City	CO_2e ton per capita
London, UK	5.9
Toronto, Canada	9.6
New York City, USA	7.1
San Diego, USA	11.1
San Francisco, USA	11.2
USA-National	24.5

Hypothetical Case Study for a Sustainable Transport Infrastructure

In metropolitan cities and urban areas dedicated elevated Personal Rapid Transit (PRT) pathways provide a sustainable solution to the urban commute and congestion by maximizing the use of existing right-of-ways of public roads [16]. This requires the selection of the "right" PRT vehicle technology that can be light weight, energy efficient, and electronically controlled. The PRT infrastructure requires the use of elevated pavements and bridge structures. Additionally, PRT operations are designed to reduce congestion and impacts on the environment by using efficient cleaner energy sources of electricity and magnetic levitation (Maglev) technology. Examples are Swedish SkyCab (electricity driven) and Brazilian Cobra Maglev vehicle/track systems [17].

The VE analysis involves determination of economic cost of such innovative mass transport technology is derived from a study of the traffic volume data for new lines, users' time savings, number of users willing to pay for such transport alternative, release of capacity on congested roads, and broader economic benefits including development of less developed regions and job creation. The life cycle economic evaluation includes several financial considerations such as present worth analysis of construction, maintenance, and operation costs and benefits over a reasonable analysis period. The LCA considers an appropriate discount rate and calculates net present value of minimum two alternatives. The base alternative is "do-nothing," and the reduction in user delay hours, less waste of fuel, and decreased emissions are considered indirect benefits from the new alternative transit strategy. The following VE example of a hypothetical case study is for a sustainable transit strategy.

To illustrate life cycle benefit and cost analysis of a PRT system the following benefits and costs are calculated and compared with the base alternative:

1. Base Alternative is Do-nothing for the existing network of roads. Assume 0% discount rate and analysis period of 10 years.

    - This will require milling and repaving asphalt roads at $1.5 million US$ per km or 15 million for 10 km roads every 5 year. The construction/maintenance cost over in 10 years is 30 million dollars.

    - The added user costs due to road maintenance will be $0.20 per veh-km. The total added user costs is (0.20 × 100,000 vehicles × 10 km × 10 years) or 2 million dollars over 10 years.

    - User delay cost due to congestion hour delays of 25 hours per year per person at $16 per hour for 0.5% traffic volume during peak hours is (0.005 × 100,000 vehicles per day × 25 hours × 16 $/hour × 365 days per year × 10 years) or 73 million dollars over 10 years. The cost of waste fuel is ignored in this calculation.

    - The total cost over 10 years is (30+2+73) or 105 million dollars. There is zero benefit or a NPV of −105 over 10 years. In 5 years the total cost is 52.5 million dollars and NPV of −52.5.

2. PRT Alternative: It is assumed that the agency cost for building a 30–40 miles/hour speed PRT system on elevated alignment may cost around 4 million US$ per km. The PRT's annual operating cost will also be significantly lower than other rail alternative due to energy efficient and light weight vehicle technology.

    - The PRT construction cost of 10-km stretch is about 40 million dollars with 0.5 million dollar annual operating and maintenance cost. Or total cost over 10 years is 45 million dollars (at 0% discount rate).

    - Assume that each person using the PRT system saves annually 25 hours of delay at $16 per hour and avoids wastage of 15 gallons of fuel and oil at $3 per gallon.

- Therefore, for 20,000 commuters (or 20% car owners in the daily traffic volume) using PRT instead of driving single occupancy cars, the total user saving is about 9 million dollars annually. The life cycle benefit is 90 million over 10 years (at 0% discount rate).

- The NPV is equal to 90 minus 45 or 45 million dollars over 10 years. At the end of 5 years the NPV is zero.

3. The PRT alternative is favored in this VE analysis after 5 or more years considering full load rate operation.

This example implies that the PRT's initial construction cost is covered after 5 years (at 0% discount rate) just by considering annual user saving. Although, this analysis simply ignores passenger fare revenue, that will be an added benefit for owner agency or operator. Additionally, the societal benefit will be significant in terms of reduction in CO_2 at 2,765 tons daily or about one million tons annually [18]. Other indirect benefits include less air pollution, reduction in associated public health cost, less risk of on-road crashes, increased productivity, and new manufacturing and service jobs. Identifying and highlighting these indirect benefits to the traveling public and other stakeholders can be a persuasive factor for the approval, funding, and implementation of the PRT system. This makes an attractive case of public-private-partnership investment for this new transport technology.

Environmentally sustainable solutions to mobility require a combination of intermodal integration strategies with reduction in gasoline vehicles on roads and increase in mass transit. Vehicles running on non-fossil fuels such as Natural Gas Vehicle (NGV), biofuel, Maglev, and other energy efficient and less polluting technologies can reduce transportation related harmful emissions and GHG emissions. Building and operating these innovative energy efficient and cleaner mass transit solutions in metropolitan areas and other large cities can be successful, if disincentives are in place to discourage commuters from driving their cars.

Concluding remarks

Urban areas and cities produce vehicle emissions and demand on energy (due to the increased built areas and population migration from rural areas) with adverse impacts on the environment, both in air quality degradation and increases in GHG emissions. Environmentally sustainable transportation management solutions to mobility require a combination of

intermodal integration strategies with reduction in gasoline vehicles, increase in mass transit, and use of non-fossil fuel. The evaluation of the competing transport technologies requires comparison of life cycle costs, user savings, and societal benefits as reduction in emissions. Public-private-partnership investment can be attracted for innovative transport technologies because rate of return is high considering value engineering analysis.

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AN EMPIRICAL REVIEW ON SUPPLY CHAIN INTEGRATION

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ABSTRACT
The purpose of this research is to review a sample of literature in the area of supply chain integration. Considering the extensive amount of literature on supply chain integration, it appears that it is still in its infancy. This study reviews a sample of 152 articles and in doing so throw light on different aspects of supply chain integration namely: vertical integration, functional integration, integration models .It discusses and criticizes the current state of literature on this context so that future researches find directions to contribute to missing points and remove obstacles. The scope of this review is limited to a cross-section of the literature in this area. As such, it cannot, and does not, attempt to be an examination of the full range of the literature, but a sampling of important and influential works.

KEYWORDS
supply chain integration, vertical integration , functional integration, integration model.

Introduction

There have been significant attempts in the extant literature to understand developments in supply chain management (SCM). The concept of SCM was first introduced by [1], who suggested that success of industrial business is dependent on the "interactions between flows of information, materials, manpower and capital equipment". But the term "supply chain" did not become popular until early 1980s [2]. Only handful of articles mentioned the phrase "supply chain" in the period 1985-1997. The acceleration in development of SCM paradigm took place only in late 1990s, with majority of theoretical and empirical investigation starting in 1997 [3, 4].

The Council of Supply Chain Management Professionals (CSCMP) defines SCM as it "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, in-

termediaries, third party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies" [5]. This paper deals with presenting an overview of integration and its various elements in SC. The terms like coordination (joint operation), collaboration (working jointly), cooperation and coordination are complementary to each other and when used in the context of SC can easily be considered as a part of supply chain integration (SCI). Integration is the quality of collaboration that exists among clusters to achieve an effective, efficient and united system. [6] define SCI as the degree to which a manufacturer strategically collaborates with its supply chain (SC) partners and collaboratively manages intra- and inter-organization processes. The eventual goal of SCI is to achieve effective and efficient flows of products and services, information, money and decisions, to provide maximum value to the end customer.

The objective of the paper is to provide a comprehensive assessment of studies in SCI. The paper